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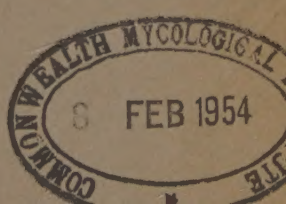

THE JOURNAL OF HORTICULTURAL SCIENCE

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SEED FERTILITY OF THE GROS MICHEL BANANA IN JAMAICA

By K. SHEPHERD

Banana Research Scheme, Imperial College of Tropical Agriculture, Trinidad, B.W.I.

Most edible banana varieties are triploids and for practical purposes male-sterile, but nearly all are at least slightly female-fertile when pollinated. Gros Michel is one such slightly fertile triploid. The functional embryo-sacs of these varieties may be the products of an irregular meiotic disjunction or they may be formed from single-, or double-restitution nuclei; thus they may be haploid, diploid, triploid or hexaploid, giving respectively diploids, triploids, tetraploids and heptaploids on haploid pollination (Cheesman and Dodds, 1942; Larter, 1948). Of these, tetraploids are the most common and, when derived from Gros Michel, are the only practicable source of new commercial banana varieties resistant to Panama Disease (*Fusarium oxysporum* f. *cubense*) and to Leaf Spot (*Cercospora musae*) (Dodds, 1943; Cheesman, 1949).

There are two reasons for studying the seed fertility of the Gros Michel banana. One is that it is inherently interesting from the viewpoint of fruit development; the other that great practical importance attaches to it as a factor in banana breeding. This paper is based on records of banana breeding operations and experiments mostly carried out in Jamaica in recent years. The Jamaican hurricane of August, 1951 put a temporary end to field experimentation and the time is thought opportune for a summary of present knowledge.

Materials and methods

The pollination data reported, except where otherwise specified, are from the cross Gros Michel × Pisang Lilan. This pollen parent is a Malayan parthenocarpic diploid with pollen fertility rather less than 50%.

The method of observation of pollen-tubes was first used at this College by B. L. Hancock (private report, 1943). Styles are from 30 to 45 mm. long in Gros Michel and 3 to 4 mm. in diameter. Detached styles are slit longitudinally with a safety razor blade just off the median line and a section about 0·5 mm. thick is removed from the larger part, in such fashion as to include the yellow-pigmented stylar canal. The section is mounted in 0·05% alkaline aqueous lacmoid and the canal is gently prised open with needles. The pollen-tubes can then, nearly always, be easily followed under a low-powered microscope.

It will be useful to outline the structure of the inflorescence and define some of the terms used. At emergence (shooting) the inflorescence of Gros Michel is contained in a compact, pendulous, ellipsoid bud formed by numerous, overlapping bracts, each, except the first few, subtending a cluster of flowers arranged in two transverse rows. The bracts lift serially, curl back and fall off, as the clusters of flowers mature and as the rachis elongates. About six to eleven clusters or "hands" of female

flowers are exposed at the rate of one to three each day and it is at this time that pollen is applied to the stigmas ; subsequently, male clusters are exposed, normally at the rate of one each day, for a period of three to four months, in which time the male rachis may attain a length of five to six feet. The male flowers persist only for about a day and then drop. The female hand contains from 12 to 24 flowers, the ovaries of which develop parthenocarpically into fruits (commonly known as " fingers ") which reach maturity in three to four months. They are invariably seedless if unpollinated.

The fruit is cut and searched at ripeness for seed. Some seeds are obviously bad when removed from the fruit, being deficient in endosperm and having immature seed-coats. Under some conditions these may constitute 12% of the total, but at Bodles station, from which most of the data are derived, they are seldom more than 2%. Of the remaining (apparently good) seeds, almost four-fifths fail to germinate, even under good greenhouse conditions. With this in mind, both " good " and " bad " seeds have been combined simply as " seed " in the following data.

Variation between bunches.

Level of fertility and variation with locality and season.

The average bunch consists of about 150 fingers and individual bunches range from roughly 80 to more than 200 fingers. Each finger contains at receptivity about 200 ovules. Yet, though as many as 40,000 ovules may have been available to fertilization, the highest recorded yield for a bunch is 60 seeds. Yields exceeding 10 are uncommon and a considerable proportion of bunches is seedless (Table I). The distribution of seeds between bunches is evidently not simple. Furthermore

Table I.

Frequencies of bunches with various numbers of seeds.

Source of results	Seeds per bunch					Mean S/B
	0	1–3	4–6	7–9	10 or more	
Bodles (January, 1950)	66	97	25	9	8	2·32
Bodles (March, 1950)	121	92	12	3	—	1·07
Holland (September, 1948–February, 1949) ..	35	63	39	19	17	3·86
Potosi (March, 1948–February, 1949)	610	66	55	19	13	0·94

there is considerable variation between localities in distribution and average yield and between different periods at one locality. The first of these aspects is elaborated in Table II. Until early in 1949, three pollinating stations had been in operation, one for seven months, the other two for some years, although detailed records are available only for the last year of operation. Holland and Potosi are both situated at the eastern end of Jamaica, the former on an exposed coastal site, the latter in a sheltered valley. Brimmer Hall is in a valley on the north coast of the island. It may be noted from this Table that at Potosi there were large numbers of infertile bunches, but the relatively few which were fertile at all were highly fertile. Holland, at the other extreme, gave a uniformly high fertility.

Bunches have also been pollinated on a very small scale in Trinidad over a number of years and some results have already been reported (Cheesman and Dodds, 1942). Yields never exceeded one seed per bunch over any considerable period and, from a new plot laid down in 1949, 88 bunches were pollinated with a total yield of only two seeds. These bunches were pollinated by male parents other than Pisang Lilan, but it is at least clear that Gros Michel at the Imperial College of Tropical Agriculture is less fertile than at the Jamaican stations.

At all stations in Jamaica for which records are available, yields are variable from month to month, from week to week, and even from day to day. Trends month by month are shown graphically in Figure 1 and ranges between months are indicated in Table II. The trends at Potosi and Brimmer Hall are roughly parallel

TABLE II.

Variation in fertility between three stations in 1948-49.

Period and Station	Total bunches	Fertile bunches	Most seeds in one bunch	Total seeds	Seeds per bunch	Range of monthly means
March, 1948–February, 1949						
Potosi	763	153	19	714	0·94	0·12–1·85
Brimmer Hall	672	371	20	1,180	1·76	0·38–2·94
August, 1948–February, 1949						
Potosi	414	37	19	207	0·50	0·12–1·18
Brimmer Hall	286	120	10	323	1·13	0·38–2·60
Holland	230	168	18	698	3·03	1·02–5·64

throughout the year, strongly suggesting a climatic effect, while, by contrast, yields at Holland showed a consistent increase from a quite low figure to an unusually high one, without any relation to the other stations.

These three stations were replaced by the Bodles station, in the relatively dry southern plain of Jamaica, at which site pollination began in May, 1949. In this month the mean yield was 1·01 seeds. The means from the three succeeding months ranged from 0·62–0·97, after which yields increased until, in the corresponding months of 1950, they ranged from 4·17–4·67. It should be said that in the early months, when the plantation was coming into bearing, very large numbers of bunches were shooting, requiring the pollinators to work late into the day. As will be shown later, this late working in itself depresses yields. However, it seems that Bodles has trends in common with Holland. Yields apparently remained high in September 1950, but few bunches could be reaped because almost all bearing stems were destroyed by a storm in October. During and after the period of recovery from this setback, yields declined to an overall average, between October, 1950 and February, 1951, of 1·36 seeds.

In an effort to account for these periodic changes in fertility, a careful examination has been made of contemporary records from meteorological stations in the vicinity of each breeding station; but of the single factors, rainfall, humidity, 7 a.m. temperature and maximum temperature, none seemed to be correlated with fertility.

The highest yields at Bodles were at a hot dry period, but so also were the low yields of the previous year. Despite these conclusions, two simple experiments were performed at Bodles to test the effect of humidity, the only climatic factor over which any control could be exercised.

As a normal routine, bunches, while being pollinated, are protected from insects by cloth bags, the necks of which are tied round the peduncle. In the first experi-

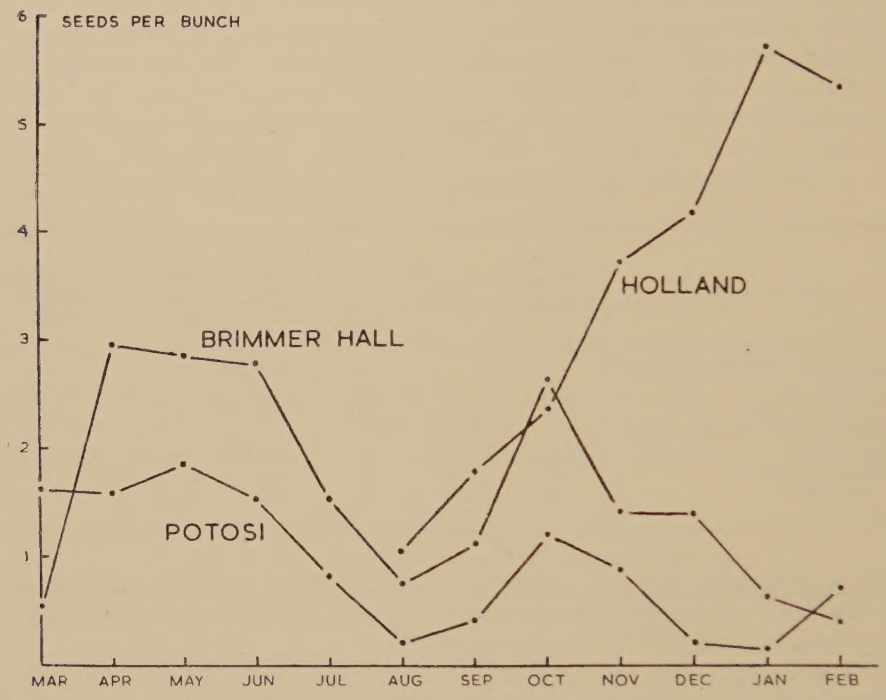

FIG. 1

Gros Michel banana. Trends in seed-production, month by month, at three pollinating stations.

ment (January–February, 1951) the bags on some bunches were soaked in water by spraying each morning after pollination, so that the air round the newly-pollinated fingers might remain saturated for at least some hours. Forty-six sprayed bunches gave a mean yield of 1·80 seeds, while 38 controls gave a mean of 1·60. In the second experiment an extra treatment was added, that of keeping the bags wet throughout the day. The results of this experiment, which again suggest a beneficial effect of spraying, are given in Table III. However, differences in both experiments are non-significant (as judged by analysis of data transformed by the square-root method) and, even if real, it is obvious that the control of humidity alone cannot produce yields as high as have occurred naturally at other periods ; nor can it be said whether the spraying treatment would increase yields which were already of a high order.

TABLE III.

The effect of wetting the bags protecting the bunches at pollination.

Treatment	Bunches	Fertile	Seeds per bunch
Wet all day	51	21	0·96
Wetted mornings only	50	24	1·08
Unsprayed	47	14	0·70

The effect of soil fertility.

Along with local climatic differences, soil fertility might be regarded as a possible governing cause of differences between localities in yields. No chemical analyses were made at the three earlier stations. It is known, however, that the soils of the Holland area are generally very low in nitrogen and potash and very high in phosphates but that there are small areas of high potash content. The soil pH is about 7·8. For Bodles, on the other hand, frequent soil analyses have been made and reveal soils uniformly low in nitrogen, medium to high in phosphates and very high in available potash. The pH values are uniformly high (7·6 to 8·2). Seed fertility and soil analyses have been recorded separately for three sections of the Bodles area. These records show that one part has persistently given more seeds per bunch than the others, although the individual bunches are not larger, and that this part coincides with the highest content of available potash and phosphate. There is thus a suggestion that seed fertility is correlated with the potash and/or phosphate status of the soil. An experiment designed to test the point was laid out but hurricane damage and disease have reduced the likelihood of getting useful results.

The effect of bunch size.

The expectation that large bunches should yield more seeds than small ones is shown to be true by the data in Table IV, drawn from the high-yielding period of

TABLE IV.

Size of bunch and fertility (Bodles, June–August, 1950).

	Hands per bunch					
	6	7	8	9	10	11 or more
Number of bunches	20	53	58	103	86	44
Seeds per bunch	1·70	2·98	2·97	4·39	5·22	6·45
Seeds per hand	0·28	0·43	0·37	0·49	0·52	0·59
Seeds per 100 fingers	2·20	3·08	2·52	3·24	3·35	3·66

Bodles station. Bunches are normally classified for size only by the number of hands they bear, but large bunches tend to have more fingers per hand than small ones. For this reason the mean yields of each class have finally been expressed as seeds per 100 fingers. It will be seen that large bunches have not only more seeds

per hand than small ones but also more seeds per finger. The same conclusions were reached from an analysis of the records from Brimmer Hall, 1948–49, while by contrast the records from Potosi and Holland showed no superiority of large bunches when totalled over several months. A reason for this can be found for Potosi. Here the mean bunch size increased steadily throughout the year and there was a preponderance of large bunches at a period when fertility was low, irrespective of bunch size. The same seemed to be true of the Holland results, where there were relatively more small bunches towards the end of the recorded period, when yields were high. Thus there appears to be a real relation between bunch size and fertility; but this relation may be confused and even concealed by variation in either factor independently of the other.

The time of pollination.

Prompted by field observations over some years, an experiment was carried out (Bodles, March, 1949) which revealed a distinct advantage from pollinating early in the morning as against later in the day. All ovaries of each of more than 200 bunches were pollinated at one or other of four set times, 7 a.m., 10 a.m., 1 p.m., and 4 p.m. The mean yield of bunches pollinated at 7 a.m. was more than twice as great as that of any other class and more than three times as great as that of bunches pollinated at 4 p.m. (Table V). Another experiment, concentrated on the range from

TABLE V.

Comparison of bunches pollinated at different hours.

	Time of pollination			
	7 a.m.	10 a.m.	1 p.m.	4 p.m.
Bunches	55	54	58	51
Fertile bunches	33	24	27	16
Seeds per bunch	1·95	0·83	0·74	0·61

6 a.m. to 10 a.m. came to an abrupt end in the storm of 1949 and no opportunity has yet been found to repeat it.

This early morning effect might be due either to the lower temperatures or to the normally higher humidity at that time of the day (cf. the indication reported above that spraying the bags improves seed yield). Whatever the cause this is evidently a most important result from the operational viewpoint.

The effect of pruning treatments.

Under favourable conditions, the Gros Michel corm attains considerable size and bears large numbers of shoots. This leads to the formation of a densely-crowded stool and, ultimately, to a reduction in bunch size ; in normal practice (commercially and in breeding) stooling is restricted by pruning to one to three leading shoots, with a like number of smaller suckers.

In 1949–50 a randomized block experiment was laid down to test the effect of pruning on seed-yields. The treatments were : no pruning ; three leading shoots

and three suckers ; one leading shoot and one sucker. Results are given in Table VI. The heavier the pruning is, the larger are the bunches, but they are less fertile.

TABLE VI.

The effect of pruning treatments on bunches and fertility.

Pruning treatment	Bunches	Seeds	Seeds per bunch	Hands per bunch
No pruning	34	145	4·26	9·3
3 bearing stems	41	160	3·90	9·6
1 bearing stem	23	56	2·45	10·0

Moderate or no pruning gave more bunches and higher overall yields of seed than heavy pruning and thus has a marked operational advantage.

The effect of fruit size.

The opinion has long been held among the pollinating staff that bunches with thin fruits more often bear seeds than do those with thick, well-developed fruits. Measurements of samples of fruits from a series of pollinated bunches at Bodles show that this is indeed so (Table VII).

TABLE VII.

Comparison of yield with finger circumference.

Circumference (inches)	Bunches	Seeds	Seeds per bunch
Up to 3¼	13	22	1·69
4 — 4¾	13	18	1·38
5 — 5¾	80	53	0·66
6 and more	26	16	0·62

It should be stated that all the fruit recorded in these observations was mature ; bunches differed from each other in environment during development and the thickness or thinness at maturity reflects the rate of development. Experiments on the chemical control of rate of development of parthenocarpic tissue are in progress in varieties other than Gros Michel and first indications are that auxins can markedly decrease female fertility.

INTERNAL FACTORS OF SEED-DISTRIBUTION.

Differences between hands.

The basal hands of the Gros Michel bunch are much more fertile than the upper hands (Table VIII). In arbitrary samples of fertile bunches from each of the four stations examined, the mean size of bunch, excluding those under seven hands, was between 7·5 and 8·4 hands, of which the first two hands contributed from one-half to nearly two-thirds of the total seed-yield, the first three hands from two-thirds to

nearly four-fifths. This behaviour does not seem to be general in bananas, for data (unpublished) on other edible varieties show little or no sign of such bias.

TABLE VIII.

Percentage of total seeds occurring in the first three hands of samples of fertile bunches.

Source	Bunches	Total seeds	Hand 1 %	Hand 2 %	Hand 3 %	1–3 %	Mean number of hands
Potosi	70	295	29·5	29·5	13·2	72·2	7·63
Brimmer Hall ..	50	205	24·4	32·2	12·2	68·8	7·56
Holland	63	368	31·2	33·4	13·9	78·5	7·79
Bodles	334	1,495	25·3	24·3	16·9	66·5	8·38

Positions of seeds in the finger.

Distances from the stylar end of the fruit pulp have been measured for 875 seeds in three samplings made at Bodles at different times. All seeds occurred in the stylar end of the fruit at distances ranging from one-half to three and a half inches from the tip. The total length of fruit pulp ranged from five to ten inches, of which all but the first half inch and the last had contained ovules in the young bunch. The greatest concentration of seeds is between one and two inches, varying slightly between the samples. The mean distance of seeds from the tip increases with total finger length (Table IX).

TABLE IX.

Mean distance of seeds (inches) from stylar end of the fruit pulp.

Sample		Finger length (inches)				
		Up to 6	6¼–7	7¼–8	8¼–9	9¼ and more
1	Numbers of seeds ..	13	53	170	140	22
	Mean distance	1·42	1·73	1·66	1·79	1·94
2	Numbers of seeds ..	25	83	107	35	0
	Mean distance	1·21	1·30	1·48	1·65	—
3	Numbers of seeds ..	96	48	30	33	13
	Mean distance	1·37	1·57	1·61	1·85	2·25

One of the three samplings was analysed for possible differences between high- and low-yielding bunches and between high- and low-yielding hands but none was found. Only very occasional fingers had more than one seed, but 40 seeds from fruits with two or more seeds each had virtually the same mean distance as seeds borne singly in the fruit.

A similar but less extreme bias within the finger has been found in other bananas, both edible and seeded (unpublished).

Cytological observations.

It was thought that the frequency of ovules containing embryo-sacs might vary under different conditions. The only comparison yet made was between two localities, Holland and Potosi. This comparison has defects in that the samples were obtained nearly three years after the relevant yield data were collected and, the original plantation at Potosi having been destroyed in the intervening period, material had to be taken from a neighbouring field. Exact data on soil fertility were lacking. The samples were segments containing about 20 to 30 ovules from newly-receptive fingers of as many bunches as were available. All segments were from identical positions in the ovaries.

Sections of the ovules were scored for stages in embryo-sac development (the sequence of events has been described by Dodds, 1945). Interpretation of the more mature stages was often difficult, particularly in the Holland material. Two conclusions were, however, reached. While there was much variation between samples, a considerably higher proportion of the ovules from Holland contained embryo-sacs (18·0% of 577 ovules, as compared with 9·8% of 407 ovules from Potosi); but, of this greater number, a higher proportion were of abnormal constitution. In the normal mature embryo-sac, five nuclei are found, the antipodals having degenerated. Instances occurred where there were one, two or three extra nuclei (presumably persistent antipodals) which often appeared as supernumerary polar nuclei. In others there were less than the normal number of five nuclei. In another, there was only one synergid and three polar nuclei, while in yet another there were three synergids but only a single polar nucleus.

A secondary conclusion was that there was no difference between proximal and distal hands in frequency of embryo-sac formation.

Pollen-tube growth.

The operation of pollen growth factors was suggested first by the concentration of seeds at the stylar end of the finger, due possibly to partial failure of penetration by the tubes. Though this is made less likely by the fact that the concentration of seeds is not entirely apical, a consideration in favour of the idea is that this is potentially a sensitive mechanism capable of reacting to day-to-day or even hour-to-hour changes in environment.

Preliminary observation on wild types of *Musa acuminata* showed that there was about a one-hour lag after pollination, during which penetration took place; thereafter the tube growth-rate was about 3 mm./hr. This was taken as a standard rate with which the Gros Michel readings were compared as a percentage, again allowing for a lag of one hour.

Tube-growth in styles of Gros Michel was found to be erratic. In all, out of 249 styles examined after 5–10 hours on a number of different days, only 11·2% showed tube lengths greater than 90% of standard, 42·6% exceeded 70% of standard, while no appreciable growth at all was found in 26·3%. The growth rate was never constant within a hand, which occasionally showed a range of values from standard growth to complete inhibition. Nevertheless, broad differences between hands were evident, some tending towards normality, some towards inhibition. On one day two hands were examined, of which only one style out of 23 showed appreciable tube-growth (more than 40% of standard). At the other extreme, on other days, two

hands (of 13 and 16 fingers respectively) had at least 70% of standard growth in every style. A few comparisons made between proximal and distal hands of a bunch gave no sign of difference in tube-growth ; but data were not numerous.

DISCUSSION.

Three main causes of female sterility in edible bananas may be envisaged : failure of pollination and/or fertilization, failure of embryo-sac development, failure of zygote development. In the case of certain diploids, Dodds (1945) showed that all three causes operated. Thus a proportion of the ovules (probably mostly proximal in the light of present knowledge) of a seeded diploid were not fertilized ; structural hybridity in the edible diploid, Pisang Lilan, led to many genetically unbalanced embryo-sacs ; and even balanced zygotes of the same edible diploid failed in early development, apparently as a consequence of interaction with an unfavourable maternal environment. Pisang Lilan, in consequence, though a diploid and gametically rather fertile, is almost entirely female-sterile and sterility is largely caused by genetical means, by the genetic system responsible at once for parthenocarpy and sterility (Dodds and Simmonds, 1948 ; Simmonds, 1953).

Gros Michel is triploid and bears so little viable pollen that its anthers never dehisce. So a field of the variety bears no seeds because natural pollination fails ; interplanting of a field with a pollen-bearing diploid would give rise to a few seeds in the commercial product. This does indeed very rarely happen and two seedlings of the Gros Michel banana were once grown at the New York Botanical Garden from seeds found in commercial fruit (A. B. Stout, personal communication to N. W. Simmonds).

In banana breeding, failure of pollination or fertilization, even though abundant pollen is supplied, is apparently a common event. Thus tube growth often fails completely, the causes of failure being unknown but perhaps related simultaneously to external climatic variables (e.g. time of day) and to internal factors, suggested by differences between neighbouring ovaries ; or it fails partially and may possibly, by failure of penetration to the proximal parts of the ovary, give rise to the marked distal bias of seed distribution described above.

Failure of embryo-sac formation is clearly very important in Gros Michel ; triploidy means that there is much gametic unbalance and presumably many sacs which are morphologically normal are in fact inviable. It is clear, however, that embryo-sacs are formed with appreciable frequency and that this frequency differs between different samples. Probably, the contemporary climate and the physiology of the plant are at least partial causes of variation. There are no means at present of estimating the importance of this factor in controlling seed fertility ; it might be negligible or it might be quite important.

Failure of zygote development, which is virtually absolute in Pisang Lilan, is, fortunately, much less complete in Gros Michel, though rather variable in incidence. It is reasonable to suppose that at least some of the differences between localities and times (i.e. soil and climatic effects), between prunings, between hands and between degrees of fruit development may be attributed to variability of failure of zygote development related to variability of the internal physiological environment of the fruit.

As to the practical consequences, even under favourable conditions Gros Michel

is not very fertile and the effort involved in obtaining seed is enormous, relative to any ordinary plant-breeding standards. Even after seed has been obtained, much of it is inviable so that to raise one tetraploid seedling requires, very roughly, 5 bunches of bananas, 250 lbs. in weight, bearing 600 fruits and 120,000 ovules. Any procedure that improves seed yields is obviously worthwhile.

Clearly no treatment or management tried can maintain seed yields at a level characteristic of the best localities at the best times. However, three points of some practical value do emerge. First, light pruning gives not only more numerous bunches but also higher inherent fertility than does heavier pruning. Second, early pollination is important. Third, the proximal hands of the bunch, being the more fertile, may with advantage be reserved to the use of favoured pollens which are scarce—this happens, for example, when a new male parent comes into use and a year or two must elapse before abundant pollen is available. In the future, manurial and spraying treatments (currently the object of further test) may also be valuable.

SUMMARY.

1. Results are reported of an analysis of female fertility in the Gros Michel banana, a nearly female-sterile parthenocarpic triploid.

2. Seed yields are found to vary with locality and time, with the size of inflorescence, the intensity of pruning, the time of day at which pollination is done and the degrees of parthenocarpic development of the fruit.

3. Seeds are non-randomly distributed within the fruit bunch, proximal flower-clusters being considerably more fertile than distal ones. Within the fertile fruits, the seeds are localized at the stylar end.

4. General features of seed fertility in parthenocarpic bananas and the practical implications of this work for banana breeding are discussed.

ACKNOWLEDGMENTS.

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REFERENCES.

Cheesman, E. E. (1949). Banana research at I.C.T.A. Trop. Agriculture, **26**, 78–84.

——— and *Dodds, K. S.* (1942). Genetical and cytological studies of *Musa*. IV. Certain triploid clones. J. Genet., **43**, 337–57.

Dodds, K. S. (1943). The genetic system of banana varieties in relation to banana breeding. Emp. J. exp. Agric., **11**, 89–98.

——— (1945). Genetical and cytological studies of *Musa*. VI. The development of female cells of certain edible diploids. J. Genet., **46**, 161–79.

——— and *Simmonds, N. W.* (1948). Sterility and parthenocarpy in certain diploid hybrids of *Musa*. Heredity, **2**, 101–17.

Larter, L. N. H. (1948). Hybridism in *Musa*. II. Somatic cytology of seedlings in relation to gametogenesis. J. Genet., **49**, 69–85.

Simmonds, N. W. (1953). Segregations in some diploid bananas. J. Genet., **51**, 458-67.

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GROWTH AND STRUCTURAL CHANGES INDUCED IN PLUM BY AN ADDITIONAL SCION

BARBARA MOSSE and R. J. GARNER

East Malling Research Station, Kent

The plum varieties President and Victoria, when grafted on the vegetatively propagated plum rootstock Malling Myrobalan B, make vigorous trees (Hatton, 1936) and exhibit no symptoms of incompatibility. Yet when President is used as an intermediate between Victoria and the rootstock Myrobalan B, the tree is dwarfed and sickly (Montgomery, Moore and Hoblyn, 1943). The first appearance of ill-health in these trees appeared to coincide with the removal of trunk laterals (or " feathers ") from the President stem. Roach and Thompson (1947), who examined one of these trees, found that a visible deterioration of the lower union corresponded with the removal of the President foliage, but that the health of the tree was not affected until all woody tissues formed previous to this had become converted into heartwood. The trees here described were constructed to test whether the presence of President trunk laterals could postpone indefinitely the symptoms of incompatibility. When, after seven years' growth, it was found that definite symptoms of incompatibility had developed in all Victoria/President/Myrobalan B trees, irrespective of the presence of President laterals, the trees were lifted and observations were made on their union structure, their root systems and the starch content of different parts. Abnormalities were found in the histological structure of the rootstock which were similar to abnormalities attributed in other plants to virus infections.

Material.

In the winter of 1940–41, at the time the original observation was made (Montgomery *et al.*, 1943), a batch of two-year-old, half-standard President and Victoria trees on Myrobalan B was planted, and three years later the well-established healthy trees, thirteen in all, were frameworked with Victoria by stub-grafting, to provide seven trees of the combination Victoria President Myrobalan B and six of Victoria/Victoria/Myrobalan B. Two months after grafting, all President trunk laterals were removed from three of the seven Victoria President trees and thereafter no leaves of President were allowed to develop on them. All the other trees including those with Victoria intermediates developed trunk laterals which were shortened as found necessary to prevent them developing into larger branches.

Growth.

The trees appeared to grow normally for three years after frameworking but in 1947 the Victoria/President trees were growing less vigorously than the Victoria/Victoria trees and had poorer foliage. A further deterioration of the Victoria/President trees was seen in 1948 and it was noted that the presence of President foliage had not reduced the symptoms of ill health but, on the contrary, had increased

them. Annual records of trunk girth, 9 in. above the lower union, showed that although the Victoria/President trees had thicker trunks than the Victoria/Victoria trees when frameworked in 1943, their growth rate fell rapidly in later years, so that by 1949 their trunks were thinner than those of the Victoria/Victoria trees (Fig. 1).

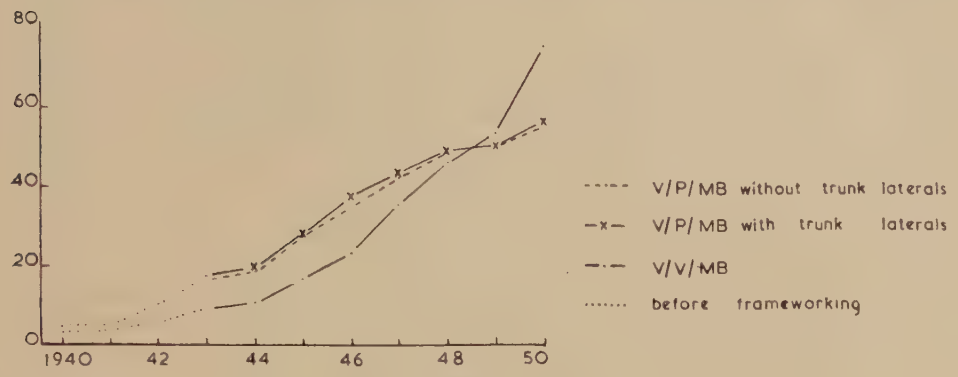

FIG. 1.
Area of cross section of trunk in sq. cm. (mean per tree).

Measurements of height and spread of the trees in 1946 and 1948 confirmed this change in relative size.

In 1946, and subsequent years, it was noted that the leaves on the Victoria/President trees were more yellow and dropped earlier than those on the Victoria/Victoria trees.

Yearling shoots were measured on all trees in 1944 and again in 1948. In 1944 the Victoria/President trees made more than twice the shoot growth of the others; but four years later the Victoria/Victoria trees made twice the growth of the clean stemmed Victoria/President trees and nearly four times as much as those with President laterals on the trunk (Table I).

TABLE I.

Growth of shoots and final weight of trunk and branches.
(Means per tree.)

Variety of intermediate	No. of trees	Shoot growth cm.		Final weight of tree without roots (lb.)		
		1944	1948	Trunk and branches	Laterals on trunk	Total
Victoria with laterals ..	6	725	2,669	52·2	6·2	58·4
President with laterals ..	4	1,795	714	30·2	2·4	32·6
President without laterals ..	3	1,583	1,280	36·3	—	36·3

In the winter of 1950–51 all the trees were lifted and the trunks cut through at 9 in. above the lower union. The trunk laterals were cut off and weighed separately from the rest of the trunk and branch system. The Victoria/President trees

were more variable in weight than the Victoria/Victoria trees and this variation was not reduced but rather accentuated in the trees with laterals from the trunk (Table II, p. 17).

CROPPING.

The trees bore a few pounds of fruit in 1947 and 1948, a moderate crop in 1949 and another light crop in 1950. Trees with President intermediates ripened two weeks before the others. The Victoria/President trees cropped more heavily in the first year, 1947, but after 1948 the position was reversed (Fig. 2). It will be seen that in 1949 and 1950 the Victoria/Victoria trees bore a greater weight of fruit and

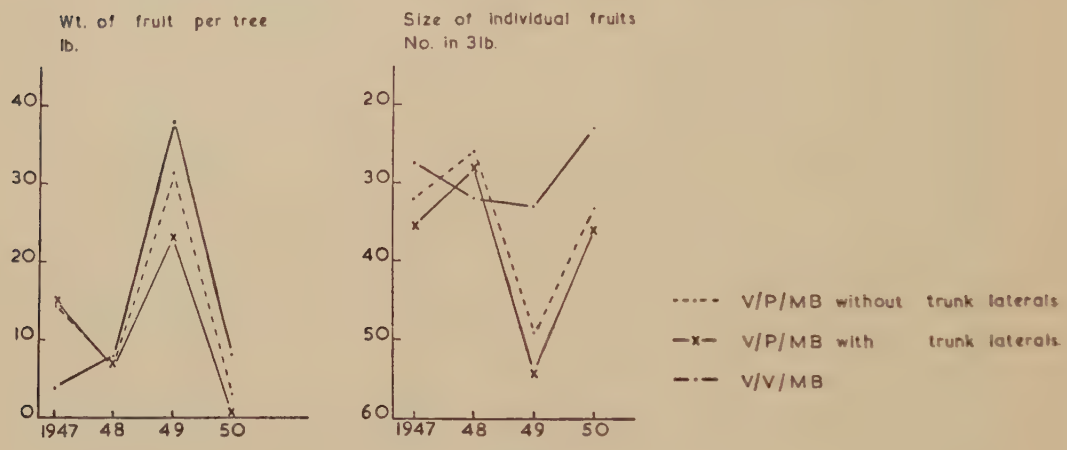

FIG. 2.
Weight and size of fruit (mean per tree).

the individual fruits were bigger than those on the Victoria/President trees. The trees with President foliage on the trunks gave the lightest crops and the smallest fruit.

UNION STRUCTURE.

When the trees were lifted the unions between the upper scion and the intermediate (two specimens from each tree) and between the intermediate and the rootstock were sawn longitudinally, and the planed surfaces examined macroscopically. Longitudinal sections of some typical unions were also examined microscopically.

Union between scion and intermediate.

Where both scion and intermediate were Victoria the unions were perfect, and it was very difficult to distinguish the junction either before or after sectioning.

In the Victoria/President unions there was a light brown line at the junction, and in most cases there was also involution of the tissues at the union (Fig. 3). This record supports the earlier observations of Herrero (1951).

Union between intermediate and rootstock.

All the Victoria/Myrobalan B unions were very good and there was no discoloration at the line of union. The trunk just below the union was slightly larger than above. The heartwood was of similar width in the intermediate and the rootstock stem, and extended over one or two annual rings.

The President/Myrobalan B unions of the seven trees examined were similar to the union described by Roach and Thompson (1947). The chief points of interest were :

1. The President/Myrobalan B union was good before frameworking with Victoria scions, and continued to be fairly good for two to three years after frameworking while the trees were making normal growth. After this period, when symptoms of ill health first appeared, vascular connection between President and Myrobalan B tissues began to break down, the degree of continuity preserved varying in different trees, and at different points in the same tree. In all trees the vascular connection tended to decrease in the more recently formed wood. The one tree in which vascular continuity had remained reasonably well established in the last two years was similar in weight to the control trees of Victoria/Victoria/Myrobalan B. The quality of the unions tended to be reflected in tree weights, but bore no relationship to the presence of President trunk laterals.

2. In most of the trees the heartwood of the intermediate was considerably wider than that of the rootstock below it, and in some cases three-quarters of the President trunk consisted of heartwood. Roach and Thompson (1947) drew attention to the spread of the heartwood in the tree they examined, and have commented on its possible significance.

3. In all except one tree the continuity of the phloem was interrupted by a layer of cork cells along the union, but continuity in the cortex was uninterrupted. Nevertheless two cases were observed where death of the cells at the union seemed to be spreading inwards from the cortex (Fig. 4).

4. In all trees with President intermediates the bark of the Myrobalan B stem just below the union was two to three times as thick as in trees with Victoria intermediates. This was mainly due to extra phloem tissues, which were highly abnormal in structure. They contained large numbers of reddish-brown to black spots and were wavy and irregular in outline where they adjoined the wood. This is also shown in Fig. 4.

ROOTSTOCK " STEM-PITTING " IN TREES OF VICTORIA/PRESIDENT/MYROBALAN B.

When the bark was stripped from the union (Fig. 5), the surface of the Myrobalan B wood was found to be covered with irregularly shaped pits of varying depth and size, mostly running in a longitudinal direction. The condition appears very similar to the stem-pitting of Mexican limes described by Wallace and Drake (1951), which is due to a virus infection transmissible from orange trees infected with the Tristeza virus. This causes a form of stock/scion incompatibility in citrus. The stem-pitting in the plum trees was confined to the Myrobalan B stem below the union, but did not extend into the roots or into the President trunk above. It did not occur at all in control trees with Victoria intermediates. Transverse and longitudinal sections were examined microscopically, and showed that the pitting was due to a localized disintegration of the cambium. Where no organized cambium remained

new cells were formed by proliferation from the much enlarged rays. The undifferentiated, unlignified tissue, thus formed, dried up or was removed when the bark was peeled off and this accounted for the pitted appearance of the wood below. This seemed so similar to stem-pitting in lime seedlings that several other staining reactions, used for the diagnosis of virus infection in other plants, were tested, to see how far modifications in anatomical structure caused by such virus diseases were similar to symptoms produced by incompatibility. Many of the phloem cells in the pitted region were necrotic and both walls and contents stained red with phloroglucinol and hydrochloric acid. Sheffield (1943), found that such a staining reaction in the primary phloem of potato stems was symptomatic of potato leaf-roll virus. The black and reddish spots observed in the macroscopic examination were identified as necrotic and suberized areas in the phloem.

Root structure.

In the trees with President intermediates the roots were a dull blackish-brown colour and, when cut transversely, the bark was abnormally wide and of a pinkish colour, while the wood was often yellow. Under Victoria intermediates the roots were light brown with a narrow bark and, when freshly cut, both bark and wood were white. When sections of the fresh roots were treated with acidified methyl alcohol many of the roots from incompatible trees stained purple with isolated spots of dark purple in the wood, while most of the roots from compatible trees remained a uniform pale pink. This staining reaction was used by Hutchins (1933) to detect phony-disease virus in peaches, and its use was extended by Bruer, Shepard and Persons (1951) to wild plums.

Two roots from each tree were fixed in formalin-acetic-alcohol and transverse sections of these, stained in Safranine and Fast Green, were examined microscopically. While the wood structure had apparently remained normal a breakdown of the phloem tissue, illustrated in Figs. 6 and 7, was characteristic of all the roots from incompatible trees with President intermediates. The breaking away of cells adjoining the rays and their tendency to collapse towards the centre of the area between two rays are very typical. In many roots no undifferentiated cambial cells remained. The orderly arrangement of phloem cells in radial files, characteristic of normal phloem and found in the roots of compatible trees with Victoria intermediates (Fig. 8), was lost completely. Ray cells and individual uncollapsed phloem cells were greatly enlarged. Frequently the contents of the ray cells were coagulated into individual droplets which stained strongly with Safranine.

To record the condition of the phloem, drawings were made of the area of uncollapsed phloem in four high power fields each located in one of the four quadrants of each section. The image was projected on to squared paper by means of a Vickers Projection Microscope and the total area of uncollapsed phloem was calculated. It should be pointed out that in the incompatible trees the phloem recorded as uncollapsed was none the less very abnormal in structure.

It was found that the stain Trypan-Blue could be used to obtain some measure of the degree of abnormality in the phloem which had not yet broken down. When sections were placed, for 30 minutes, in a 0·05% solution of Trypan-Blue in 0·85% salt solution, collapsing cells and part or even the whole contents of some of the sieve tubes acquired an intense blue colour, Fig. 6. McWhorter (1941) found that Trypan-

Blue used in this way was effective for demonstrating the presence of certain plant viruses within infected tissue. In the plum roots the shape and location of many of the stained areas suggest that it may be the callose pads, or substances adsorbed on these which give the reaction. It is known that callose pads form in sieve tubes when they cease to function. A count was made of the number of cells stained with Trypan-Blue which lay within a ring, 158μ in width, outside the cambium. Table II, column (iii) shows, for two roots per tree, the number of cells stained with Trypan-Blue per unit area of uncollapsed phloem. Column (ii) gives, for two roots per tree, the mean area of uncollapsed phloem expressed as a percentage of the total area of phloem measured ; column (i) shows the tree weight.

TABLE II.

Weight of trees and measurements of the amount and condition of the uncollapsed phloem in their roots.

Victoria/President/Myrobalan B			Victoria/Victoria/Myrobalan B		
(i) Weight at lifting (lb.)	(ii) Percentage area of uncollapsed phloem	(iii) No. of cells stained with Trypan-Blue	(i) Weight at lifting (lb.)	(ii) Percentage area of uncollapsed phloem	(iii) No. of cells stained with Trypan-Blue
*17	3·5	272	*46	52·4	5
21	1·2	215	*51	64·6	11
31	15·9	115	*57	71·5	7
*32	14·6	65	*63	54·4	10
*40	7·8	160	*67	64·5	3
*41	26·2	72	*67	65·4	6
57	20·6	81			
Mean 34	12·8	140	58	62·1	7

Figures marked with an * represent trees with trunk laterals.

Differences in the condition of the phloem in roots of compatible and incompatible trees are shown clearly by these figures. In the trees with President intermediates there is a negative correlation coefficient ($-0{\cdot}838$, $P<0{\cdot}05$) between the amount of uncollapsed phloem and the number of cells stained with Trypan-Blue. This indicates that the two records support each other in providing a measure of the degree of abnormality in the phloem. For the trees with President intermediates the correlation coefficient between tree weight and the amount of uncollapsed phloem is $+0{\cdot}742$, $P=0{\cdot}056$. Neither correlation even approached significance in the trees with Victoria intermediates, and it is concluded that for these the records represent the normal range of variability in healthy trees.

STARCH CONTENT.

The starch content of the wood in three roots, three scion shoots, three trunk laterals and samples taken from either end of the intermediate trunk was estimated by recording the depth of colour developed when longitudinal sections of these parts were treated with iodine in potassium iodide solution. The depth of colour was recorded in categories, each sample being recorded separately.

It was found that in all the incompatible Victoria/President trees, with or without trunk laterals, the roots contained very little or no starch while the shoots contained much and fell into the highest category recorded. All the compatible trees with Victoria intermediates had a high starch content in the roots and in each case a somewhat lower content in the shoots. There was thus a reversal of the starch gradients in compatible and incompatible trees. In one tree where the President intermediate had scion rooted, the starch content of the Myrobalan B roots on the scion-rooted side was much higher than on the others. The starch content of trunk laterals was generally low. In all trees with trunk laterals there was a similar starch content at either end of the trunk. In two President trunks without laterals there was a distinct starch gradient with higher starch content at the base, and in the third trunk there was a slight gradient in the same direction. Changes in starch content did not occur suddenly at the union.

DISCUSSION.

The incompatibility which results when trees of President on Myrobalan B are frameworked with Victoria, is of particular interest because some of its features are typical of incompatibility in fruit trees while others are fundamentally different. The gradual falling off in growth, poor leaf colour and defective union structure, leading sometimes to breakage at the union, are characteristics of incompatibility in plums. The case is exceptional because the incompatibility is induced between two normally compatible graft components, President and Myrobalan B, by the introduction, more than five feet above this union, of the variety Victoria, which is itself compatible with the rootstock. No similar case has been found in the literature, not even in that concerned with the virus incompatibility of citrus or the nutritional incompatibility of melon on certain cucumber stocks (De Stigter, 1951).

The possibility that the President foliage might assist in the nutrition of the roots was investigated by leaving laterals on the President trunk. Though the presence of these leaves in no way lessened the symptoms of incompatibility, yet the very low starch content of the roots of all the Victoria/President trees shows clearly that a starvation of the root system is one of the effects of this incompatibility.

There was much evidence that the tissues of the rootstock were the most seriously affected. A break-down of the phloem in Myrobalan B rootstocks grafted with incompatible peach scions was first recorded by Herrero (1951). The correlation found between the weight of individual Victoria/President/Myrobalan B trees and the degree of abnormality in the phloem of their roots will be of great interest if it can be confirmed by further work. The variation in the performance of individual trees of the same incompatible combination, shown by the weight of Victoria/President trees (Table II), is a characteristic feature of incompatibility in fruit trees, and will require explanation before the problem can be fully understood. If abnormalities in the root-structure could furnish an index of the degree of incompatibility, this would have the obvious advantage that the trees to be tested need not be destroyed, but could be replanted after their roots had been examined, and their subsequent growth checked against the earlier records.

The suggestion has been made that, as in citrus, incompatibility in fruit trees may in some cases be connected with the presence of a virus in one or more of the graft components. The action of the Victoria scions on the President/Myrobalan B

PLATE I

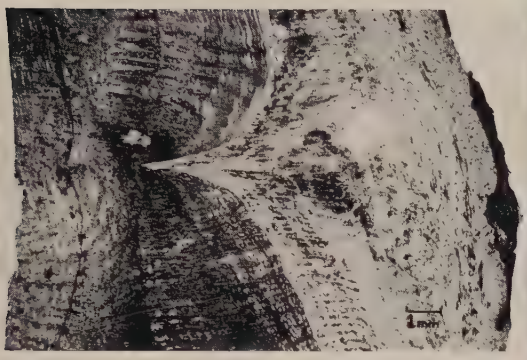

Fig. 3.

Longitudinal section of the union between scion and intermediate in a tree of Victoria/President/Myrobalan B.

Fig. 5.

Trunk of Victoria/President/Myrobalan B with bark removed from the lower union to show stem-pitting of Myrobalan B rootstock, and discontinuity of the woody tissues at the union.

Fig. 4.

Longitudinal section of the union between intermediate and rootstock in a tree of Victoria/President/Myrobalan B. (Arrows mark the line of demarcation between the living and dead cells in the cortex.)

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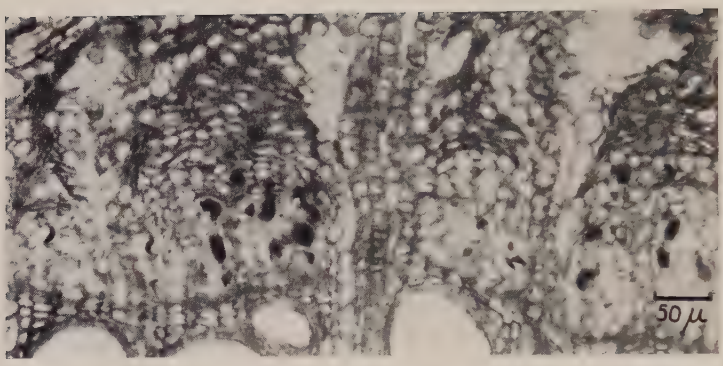

FIG. 6.

Transverse section of the phloem, stained with Trypan-Blue, in the roots of a tree of Victoria/President/Myrobalan B.

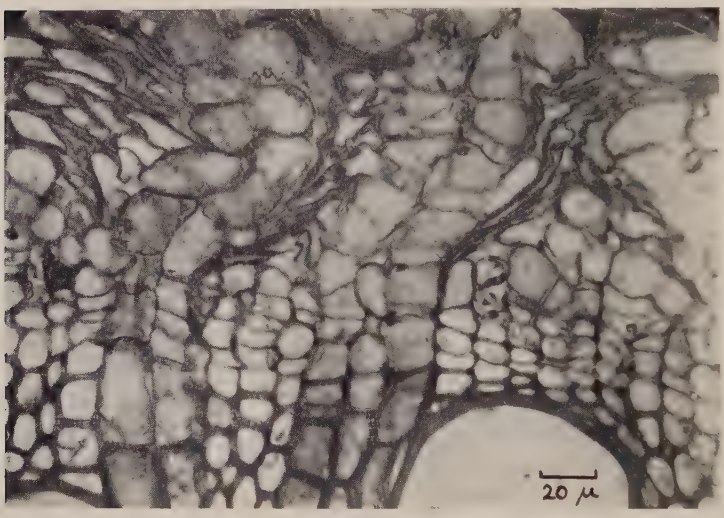

FIG. 7.

Transverse section of the abnormal phloem in the roots of a Victoria/President/Myrobalan B tree.

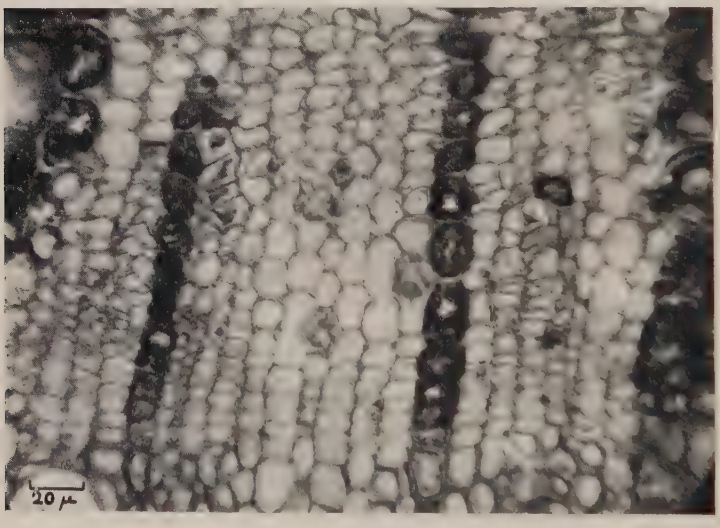

FIG. 8.

Transverse section of the healthy phloem in the roots of a Victoria/Victoria Myrobalan B tree.

union, several feet distant, and the variation between individual trees might be explained on this basis. The stem-pitting of the rootstock, and abnormalities of the phloem which have been described are very similar to the effects produced by viruses in other plants. On the other hand Esau (1948) concluded "that the type of [anatomical] alterations induced in plants by viruses depends upon the reactions of the host as well as upon the activity of the virus, and that these reactions are usually fundamentally similar to those released by various agencies other than viruses". It may well be that the abnormalities found in the Myrobalan B rootstock in incompatible trees are the result of the general ill-health of the trees, and not in this case a specific reaction to the presence of a virus. Experiments are in progress to test this.

SUMMARY.

Five-year-old trees of President and Victoria on the rootstock Myrobalan B were frameworked with Victoria and observed for a further seven years. On four of the trees with President trunks, laterals of President were allowed to grow. Symptoms of incompatibility developed in the Victoria/President/Myrobalan B trees, and these were in no way lessened by the presence of President laterals.

A histological examination was made of the union structure, the root structure, and the starch content of different parts of the trees. Trees with President trunks showed abnormalities in the following features:

1. A condition of "stem-pitting", due to a localized disintegration of the cambium, was found in the Myrobalan B rootstock stem below the union.

2. The structure of the phloem in the roots was highly abnormal. Measurements of the amount of uncollapsed phloem and its staining reaction with Trypan-Blue showed some correlation between the degree of phloem abnormality and individual tree weight.

3. All trees with President trunks contained much starch in the shoots and little or none in the roots, while the starch content of trees with Victoria trunks was high in the roots and somewhat lower in the shoots.

REFERENCES.

Bruer, H. L., Shepard, C. E., and *Persons, T. D.* (1951). Survey of phony incidence in wild Prunus. Plant Dis. Reptr., **35**, 186-8.

De Stigter, H. C. M. (1951). The influence of stock foliage in an incompatible cucurbitaceous graft. Koninklijke Nederlandse Akad. van Wetenschappen. Proceedings 54c (1), 58-65.

Esau, K. (1948). Some anatomical aspects of plant virus disease problems II. Bot. Rev., **14**, 413-49.

Hatton, R. G. (1936). Plum rootstock studies: their effect on the vigour and cropping of the scion variety. J. Pomol., **14**, 97-136.

Herrero, J. (1951). Studies of compatible and incompatible graft combinations with special reference to hardy fruit trees. J. hort. Sci., **26**, 186-237.

Hutchins, L. M. (1933). Identification and control of the phony disease of the peach. Ga. State Ent. Bul., **78**.

McWhorter, F. P. (1941). Plant virus differentiation by Trypan-Blue reactions within infected tissue. Stain Technology, **16**, 143-8.

Montgomery, H. B. S., Moore, M. H., and *Hoblyn, T. N.* (1943). A field trial of measures designed for the control of bacterial canker of Victoria plum trees. Rep. E. Malling Res. Sta., for 1942, 53-61.

Roach, W. A., and *Thompson, E. C.* (1947). Examination (after injection with a dye) of a double worked plum tree showing incompatibility. J. Pomol., **23**, 212-7.

Sheffield, F. M. L. (1943). Value of phloem necrosis in the diagnosis of potato leaf-roll. Ann. appl. Biol., **30**, 131-6.

Wallace, J. M., and *Drake, R. J.* (1951). Newly discovered symptoms of quick decline and related diseases. Citrus Leaves, **31**, 8-9, 30.

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TRIALS OF BURNING AND MOWING STRAWBERRY PLANTS AFTER CROPPING

By DOROTHY J. WILSON and W. S. ROGERS
East Malling Research Station, Kent

It has long been known that setting fire to the straw at the end of a strawberry picking season when the weather is suitable, is a quick, cheap and efficient way of cleaning up the field. If the straw is dry, a rapid even fire destroys litter and weeds and removes most of the leaves of the strawberry plants. There is no doubt that it also substantially reduces the population of insect pests and the spread of mildew and the leaf spot group of diseases, an aspect of the operation which is not considered in the present paper.

Often if the blaze is fierce, the above-ground parts of the strawberry plant are almost completely charred. Growers know well how quickly the plants start into growth again, especially after rain, but have expressed anxiety lest this drastic "pruning" may cause a reduction in subsequent crops. An answer to the question whether burning is harmful to the plants and, if so, to what extent, has been sought in a series of experiments.

Three trials can now be described. The first, with Royal Sovereign, compared burning with the standard practice of removing the straw, weeds and runners. In the other two trials, burning was included as an after-crop treatment in cultural trials of Huxley in which the plants were being grown as matted beds 3 ft. wide, and matted rows 18 in. wide, as well as in normal spaced rows. The comparison of planting systems will be described elsewhere, but the differences shown between the treatments described here held good for all three planting systems. In both trials, mowing the strawberry leaves and removing them with the litter was also tested, to find whether the effect of burning was simply the result of destroying the leaves or whether it involved other factors. The standard clearing up of litter was included as a control.

Crops were recorded in the season after treatment by picking into two market grades, grade 1 large sound fruit of $\frac{7}{8}$-in. diameter and over, and grade 2 sound fruit of smaller size, with a third grade for damaged or rotten fruit. Plant size was measured in the spring following treatment in trial 1, and in trial 2 for spaced plants only.

Trial 1.

A field had been planted with maiden runners of Royal Sovereign in October, 1938 with rows 33 in. apart and the plants at approximately 15 in. in the row. After picking the crop in 1941, sixteen guarded plots, each containing 2 rows 42 ft. long, were marked out. From every pair of plots one was selected at random and burnt over on 21st July. The fire burned well, but a little extra straw was added to some of the rows to ensure even burning.

Two thermometers, suspended by corks in $\frac{3}{4}$-in. test-tubes containing 20 cc. of water, were placed amongst the plants to act as a standard heat measure and to give

some indication of the temperature to which strawberry crowns were subjected during the burning. The base of the test-tube rested on the soil and the thermometer leaned at an angle of about 45° against a bent wire support. Before the straw was ignited these thermometers registered 24·2° C. and 23·3° C. and, as soon as it was possible to reach them after the flame had passed, they read 38·9° C. and 41·1° C. respectively. After a further four minutes they had fallen again to 38·7° C. and 40·0° C. The highest reading is probably very near the maximum temperature reached by the water in the test-tube, and was obviously not maintained for more than a few minutes. As is well known, strawberry plants can be subjected to warm water treatment of 110° F. (43·3° C.) for 20 minutes for the control of Tarsonemid mite, with very little effect on the plants. It is therefore unlikely that, in this experiment, the crowns of the plants, which were in roughly the same position above the soil surface as the test-tubes of water, can have been damaged, even though the leaves and straw above and around them were actually on fire. In fact, ten days later, clean new leaves were emerging.

In May of the following year there was no visible difference between the plants on the burnt plots and those which had not been burnt, and measurements of the heights and spreads of all the plants showed the means for the two treatments to be almost identical.

The crop figures for 1942 (Table I) showed that the yield from the burnt plots was 22·4% greater than that from the unburnt plots. Far from reducing the yield, burning had been followed by a substantial and statistically significant increase.

TABLE I.

Burning and cutting strawberry foliage. The effect on crop weight.

			Marketable crop—cwt. per acre			
Trial	Date	Variety	Control	Cut	Burnt	Significant difference
1	1942	Royal Sovereign	24·9	—	30·5	3·5
2	1950	Huxley	72·6	88·6	71·5	13·5
	1951	Huxley	57·5	72·3	81·4	15·8
3	1951	Huxley	66·3	79·4	81·4	11·0

P=0·01 for Trial 1 and 0·05 for Trials 2 and 3.

TRIAL 2.

Runners of Huxley M.44 were planted in October, 1947 for this experiment. A split-plot design accommodated the three planting systems (spaced rows, matted rows and matted beds) arranged at random within 12 guarded blocks. The after-crop treatments, viz. (*a*) burning, (*b*) cutting, and (*c*) removal of litter and runners, randomized on these larger plots, were thus each replicated four times. In their maiden year the plants were deblossomed and the runners either cut off or laid in where required to form matted rows or beds. They cropped for the first time in 1949 which was an exceptionally dry season, and many plants were in a wilted condition when burning took place.

On the morning of 12th July, the (*b*) plots were mown (with a small reciprocating mower) and the leaves, runners and litter raked up and removed. The (*c*) plots were cleaned up at the same time and in the afternoon the (*a*) plots were burnt. The day was hot and sunny with a brisk east wind and the fires burnt fiercely.

In this and later experiments the temperature inside typical strawberry crowns was measured with a thermocouple during burning. The thermocouple was made of 26 s.w.g. copper/constantan wires insulated to within $\frac{1}{8}$ in. of the hot junction by glass beads and bound with asbestos string for about 1 ft. Loose petiole bases were removed from a selected crown in the middle of each plot and the thermocouple was pushed into the tissues up to the glass insulation. The thermocouple leads were then carried down into the soil and buried about an inch deep until well beyond the area to be burnt. Readings of the galvanometer connected to the thermocouple were recorded at intervals of 15 seconds from the moment the straw was ignited until well after flames and smoke had ceased.

The temperature recorded on three plots can be seen in Fig. 1a. On plot 3 the thermocouple was on the leeward side of a plant which was incompletely burnt, and only registered a slight rise. The fourth plot was burnt at the same time as the first, which it adjoined, so no separate temperature record is available for it.

On the following day the plots presented a literally " scorched earth " appearance. Most of the plants were reduced to a white ash with an occasional charred petiole still standing, and the rest had scorched, brown or blackened leaves with charred petioles.

About a quarter of an inch of rain fell in the following week and by the end of it a few green leaves were emerging on the cut plots. At the same time a few of the burnt plants began to unfold a new green leaf and these showed no sign of damage when they opened ; but most of them, especially the one-year-old crowns in the matted beds and rows, made no visible growth for some time. Bindweed, with which some plots were infested, though destroyed to ground level in the burnt plots, was growing strongly again four weeks later and weeding to remove this was necessary five weeks after burning. By mid-September it was clear that some strawberry crowns were dead but enough young plants had survived to maintain the matted plots and very few of the older plants had been completely killed. The plants in which thermocouples had been placed were all growing well, though the new leaves of the plant on plot 1 were arising below the point where the thermocouple had been inserted. This suggests that the tissues which sustained a temperature of 73° C. did not survive, although nearby buds were not injured.

Growth the following spring was good but in May the burnt plants (mean spread on spaced plots, 12·2 in.) were significantly smaller than the cut ones (14·1 in.) or those on the control plots (14·4 in.).

The yield of the burnt plots the following summer was 1·5% less than, but not significantly different from, that of the control plots. Mowing gave the highest yield, significantly better than either burning or the control treatment (Table I).

After the 1950 crop was picked, the experiment was repeated by applying the same cleaning treatments again to the same plots. This was not such a dry season as 1949 and although some wilting occurred in early June, especially in the matted rows and beds, it was not widespread and, at the time of burning, the plants were in better condition than they had been in the previous year. Mowing was carried out in the afternoon of 10th July, and some rain fell overnight. As the straw was damp

the next morning, it was raked up on top of the plants and a little extra brought in to cover the matted beds evenly. It dried sufficiently for burning to be carried out that afternoon.

The highest maximum temperature reached was 67° C. on plot 1 (Fig. 1b).

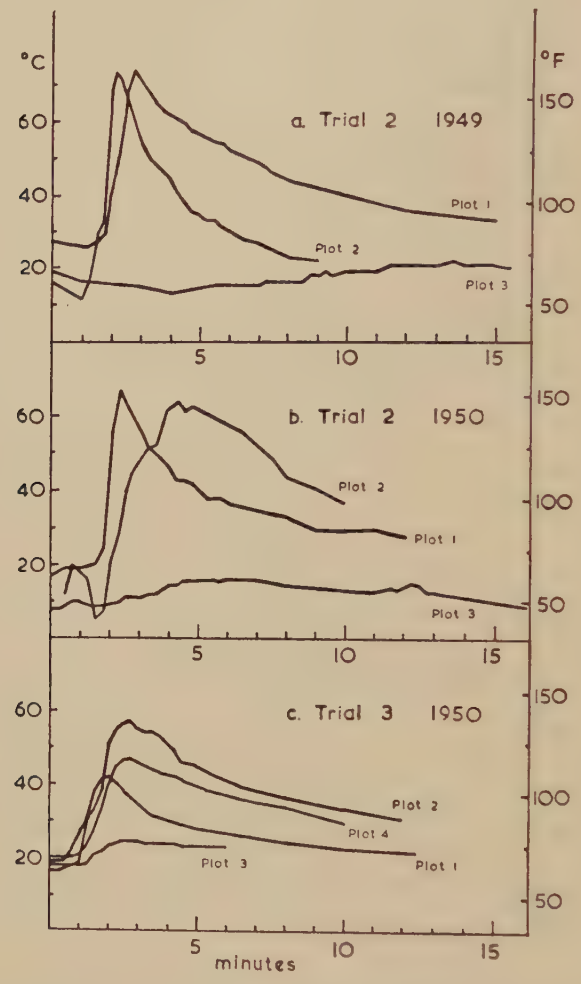

Fig. 1.

Temperatures recorded during burning, with the thermocouple inserted in the crown of a strawberry plant.

On plot 2 the selected crown reached a maximum of 64° C. and on plot 3 it did not rise above 16·2° C. As the straw was still rather damp, the fires were not nearly so fierce as in the previous year and patches had to be re-ignited where they had escaped the flame. At the end of the operation some leaves had been burnt right off but most were simply dried and scorched.

Next day almost all the leaves on the burnt plots were brown and dead but a small patch was still green near the plant which had carried the thermocouple on plot 3. Within a week, young leaves were expanding on all plots and, within a month, the plants were growing well. Weed growth was also rapid. Cut and control plots needed hoeing by 18th July but burnt plots remained cleaner for a week or two.

The crop of marketable fruit from the burnt plants was significantly higher than from the controls (Table I). The yield from the cut plots came between the other two treatments and did not differ significantly from either.

TRIAL 3.

Planted a year later, this trial was in most respects similar to trial 2. The same after-crop treatments were applied at the end of the first harvest in 1950, mowing being carried out on the same day as in trial 2 (10th July) and burning two days later.

The fires burned well but not too fiercely and at the end of the operation many dry and scorched leaves remained. The maximum temperatures recorded by the thermocouple on the four plots were 42° C., 57° C., 24·5° C., and 47° C. (Fig. 1c). Burning was very superficial around the thermocouple on plot 3.

Six days later young leaves were opening on the cut plots and a few also on the burnt plots. A month later both treatments showed strong new growth. In spring 1951 foliage was good on all the treatments and there was no visible difference between them.

As in trial 2 in the same year, the plots which had been burnt produced the greatest yield of marketable fruit and both burnt and cut plots cropped at about 4 tons to the acre, significantly better than the controls at $3\frac{1}{3}$ tons per acre (Table I). Both these treatments also gave a higher percentage of first grade fruit than the control.

DISCUSSION.

These experiments provide substantial evidence that healthy strawberry plants are not injured by the practice of burning over after harvesting. Indeed in most trials the burning caused a valuable improvement in the subsequent crop. Even with the rather low yield from the Royal Sovereign plants in trial 1, which were then giving their fourth crop, the increase was $5\frac{1}{2}$ cwt. to the acre and, in 1951, one Huxley crop was improved by more than a ton per acre and the other by 15 cwt.

These plants were not seriously affected by drought, the fires were only moderately fierce, and though almost all the leaves open on the plants at the time were killed, very few crowns failed to produce new growth.

The first year of trial 2 was exceptional in that the plants were suffering severely from water shortage and there was little or no weed foliage to check the intensity of the fire. Many of the young crowns in the matted rows and beds were killed and some of the older plants were left with only one or two living crowns. That the crop was reduced by only 1·5% below that of the controls indicates that the crowns which survived the fire cropped much more heavily than those in the control plots.

The peak temperatures recorded by the thermocouple seldom existed for more than a few seconds and were probably not reached throughout the crown. Since the plant tissue itself is about 80% water, a large amount of heat is absorbed in

evaporating this before charring can occur and thus tissues may remain undamaged quite near to parts which are actually burnt. Furthermore, a very steep temperature gradient must exist between the soil, with the relatively cool air stream just above it, and the flames themselves.

The substantial crop increases following the mowing of old leaves after harvest indicate that much of the effect of burning can be attributed to the removal of old leaves. Such removal reduces, for a time at least, the amount of water lost by the plant in transpiration and so may help it to recover from the effects of a soil water deficit. This must have been of great importance in 1949 when the plants were wilted.

A good fire will destroy most of the annual weeds, which by the end of the picking season are often fairly large and well established. It also gets rid of much potential weed seed and checks perennial weeds. This weed clearance, though of limited duration, delays the need for cultivation at a busy time.

Cutting assists to a less extent in weed control and cultivation is soon necessary.

In conclusion, therefore, burning after harvesting can be recommended as a cheap and beneficial practice in most years. It is risky in severe drought and is not practicable if the straw is very wet and weedy.

Cutting off the leaves, though not quite so cheap, offers similar advantages, involves no risk, and is practicable in all weathers. It can be recommended whenever burning is not suitable.

SUMMARY.

Three trials are described in which strawberry plants were burnt or cut after cropping. The crop following burning was heavier than that of control plots, except when wilted plants were burnt. The crop after cutting was always greater than that from the controls. It appears that the advantages gained from these treatments are associated largely with the removal of the leaves themselves. Temperatures within crowns of strawberry plants were measured by means of a thermocouple during the burning operations and often exceeded 60° C. (140° F.) for short periods.

ACKNOWLEDGMENTS.

The authors wish to express their thanks to Mr. C. H. W. Slater who made the thermocouples and set up the apparatus for measuring temperatures inside the plants.

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PROPAGATION OF PLANTS BY ROOT CUTTINGS

I. REGENERATION OF RASPBERRY ROOT CUTTINGS

By J. P. HUDSON
Department of Horticulture, University of Nottingham School of Agriculture, Sutton Bonington

SYNOPSIS

Some varieties of raspberries can readily be propagated from root cuttings. The method is more rapid than the traditional use of root suckers and might be useful in the initial multiplication of raspberry clones. Recommendations are made regarding choice and preparation of parent root material, method of making and planting cuttings, and subsequent management of the plants produced. The behaviour of raspberry root cuttings at various seasons and in different environments is described and discussed.

In Britain, raspberries are propagated by transplanting dormant root suckers in the first winter after they have grown from their parent roots.

Stock of a new raspberry clone is worked up by planting the parent in winter and, a year later, cutting down or transplanting the few new suckers which have grown, but leaving most of the roots in the ground. A few dozen rooted suckers should be produced by the second winter. The rate at which a raspberry clone can be thus increased depends upon the freedom with which suckers are produced, the amount of root produced and the capacity of pieces of severed roots left *in situ* to produce new suckers.

For propagating established varieties, root suckers used to be dug from fruiting beds but more recently have been raised in cane nurseries cultivated specially for the purpose. In the management of cane nurseries, described in detail by Grubb and Harris (1945), Wood (1949) and others, the whole area is cleared of aerial growth each winter by digging out all root suckers. During the next year many new suckers grow from the roots that remain and are in turn dug at the end of the season. The rate of production of rooted suckers varies enormously and counts from established beds have ranged from 25,000 to 150,000 per acre but yields of 40,000 to 60,000 per acre are quite normal. The method enables new plants to be produced at a high level of management and hygiene, yet in sufficient quantity and at a suitable price for commercial planting.

Despite the success of the cane nursery system, there might be advantages in other methods of propagation, especially when plants are to be sent from one country to another and for the speedier building-up of stocks of new clones. A few root cuttings taken in March, 1949 regenerated rapidly and stimulated interest in this method, which appeared to offer certain advantages. For instance, root cuttings are far less bulky and heavy than suckers, and can usually be obtained in large numbers from raspberry plants after only one season's growth. Their use for propagating raspberries has therefore been investigated.

REVIEW OF THE LITERATURE.

The author is aware of only one reference, in the British literature, to the propagation of raspberries from root cuttings (Hudson, 1950), although in cane nurseries the new season's plants must, of necessity, come from a form of " whole root cutting ", i.e. the severed roots left in the soil after removal of the previous year's suckers.

Several forms of root cuttings appear to be used for propagating raspberries in America. Kains and McQuesten (1945) suggest that old plants should be dug round deeply, 6–8 in. from the stool and again further out, or the ground deeply disced after removing the old stools, to cut up the roots. Each piece of root left in the ground may produce a new plant which is transplanted the following winter. Another way is to lift roots in autumn, and cut them into lengths which are kept damp in a cool place until spring. " The callused ones are then planted like peas, in nursery beds where they make saleable plants by the following autumn." This suggests a difference between American and British varieties ; in the present work no callus formation has been observed amongst several thousand cuttings grown and examined.*

Butterfield (1947) suggests that pieces about 3 inches long, cut from the roots of old stools and lined out in nursery rows, should produce plants fit to set out in the fruiting plantation a year later. Jansen has recently reported (1952) that, in Holland, Rietsema has developed a method of propagating raspberries from root cuttings. Small pieces of roots, at least $1\frac{1}{2}$ mm. thick and about 3 cm. long, have been used in spring, selecting for the purpose pieces that have each at least one bud or shoot.

EXPERIMENTAL METHOD.

Since 1949, experiments have been carried out to ascertain whether root cuttings could be used for propagating varieties of raspberries grown in Britain and, if so, the best time of year, the most suitable type of roots, methods of selecting and using roots and the best subsequent treatment for plants so produced.

Batches of roots were dug at intervals, washed, and made into cuttings which were then put in various environments to grow. Information was recorded on the past history of the plants from which roots were dug, on the nature of the roots and cuttings, on the environments in which the latter were grown, and on the behaviour of cuttings until they had either regenerated or died.

Most of the work has been done with the varieties Lloyd George (New Zealand stock) and Malling Promise, but small batches of the following varieties have also been propagated successfully in the same way : Malling Enterprise, Malling Exploit, Malling Jewel, Malling Landmark, Malling Notable, Malling Seedlings G and K, Newburgh, Norfolk Giant, Romy and St. Walfried.

In America relatively old plants seem to be used as the source of root material. Since the main purpose of the present work was to develop a rapid method of

* The varieties of raspberries grown in Britain (and used in this work) are all of the same " red raspberry " type, believed to have originated from the common wild species *Rubus idaeus*, L. On the other hand, three distinct types are grown in the United States, viz. red, black, and purple-cane raspberry (Hedrick, 1925) ; all probably of different origin from British varieties (Darrow and Waldo, 1948). There is great variation in the methods by which *Rubus* species propagate vegetatively in nature and in horticultural practice, and root cuttings can be used for increasing blackberries (Potter, 1936 ; Swartwout and Martin, 1942) and various ornamental species.

propagation, the advantage lay in using roots at the earliest possible stage and young roots were therefore used throughout. It was not practicable to determine the exact age of any particular piece of root, but the time which had elapsed since the parent was planted established the *maximum* possible age of each piece. Most roots were less than two years old when dug.

Lifting and selection of roots.

Roots were dug out to a depth of about 25 cm. There was little breakage of roots when the soil was moist but they were much damaged when lifted from hard, or frozen soil. The roots were rinsed under running water for ease of scrutiny, sorting and preparation. Appearance gives a good guide to their condition although, of course, the presence of virus diseases cannot be detected by examination. In a healthy root the bark is firm and brightly coloured, ranging from pale yellow to dark brown depending on age and variety. The first sign of lack of vigour is a change in the bark, which becomes dull and darker than normal. The wood also darkens from cream to dark yellow or brown, whilst thin lateral and feeding roots become yellow and translucent. At the latter stage, roots can be regarded as moribund and are rarely, if ever, able to regenerate. Roots which looked unhealthy when lifted were discarded, but the great majority were in good condition.

Adventitious buds develop naturally on all types of raspberry roots except the thinnest, short-lived feeding rootlets, but most are found on main roots up to two years old. They appear at irregular intervals, sometimes as many as ten buds per cm., although usually more widely spaced. Buds have been found on roots which were less than two months old. Observation of a sample of five hundred buds suggests that they may equally appear on the top, sides or underneath surfaces of roots and although most buds fail to make any further growth, their chances of developing into shoots appear to be equally good whatever their orientation.

Although buds can be found at all seasons they are most conspicuous from autumn to spring, when buds and shoots can be found at all stages of development up to young root suckers with rosettes of leaves at ground level (Fig. 2). Elongating buds and rosetted shoots are often undamaged by lifting but etiolated shoots without leaves are fragile and usually break off.

Preparation of root cuttings.

Badly contorted roots, pieces less than 1 mm. in diameter and those where the cortex had not yet been completely sloughed off, were discarded. The remaining roots varied in diameter from 1 mm. to about 5 mm., but were mostly in the 2-4 mm. range. All these were cut into convenient pieces, mainly from 8 to 12 cm. long (Fig. 1).

Many cuttings bore buds, which were not removed but, in the early stages of the work, elongating shoots were usually cut off because of difficulty in planting roots without injuring them. Later, they were left because their removal seemed to reduce the capacity of cuttings to grow.

The main roots are normally furnished rather sparsely with laterals, which in turn carry systems of fibrous feeding rootlets, but some of these break off when lifted. Those that remained were usually left intact unless too numerous or long

for convenience of planting, when they were cut off a few centimetres from the main root.

Care was taken to prevent roots from drying out whilst they were being lifted, sorted and cut. Cuttings were then kept damp until they were planted. Records were made of the length and average thickness of each root, its colour and general appearance, the number, colour and type of visible buds, and the amount and type of lateral and/or feeding roots.

Environments for propagation.

In the main experiments the cuttings were divided into strictly comparable groups which were planted horizontally in three different environments :

A—*Cool glasshouse, in compost.* At 1–2 cm. deep, in boxes of John Innes Potting Compost No. 1, on a bench in a heated glasshouse kept at moderate temperatures.

B—*Cold frame, in soil.* At 2–3 cm. deep, in rich garden soil, in frames covered by Dutch lights, kept closed except for watering and recording.

C—*Out-of-doors, in full sun, in soil.* At 3–5 cm. deep, in old arable soil in the open ground in full sun.

In general, the minimum soil temperature at 3 cm. in the cold frame (Env. B) was 3–8° F. higher than in the open ground (Env. C), whilst the minimum soil temperature in the glasshouse (Env. A) was a few degrees higher still. Mean soil temperatures at 3 cm. depth in the glasshouse and cold frame were roughly fifteen and ten degrees higher, respectively, than in the open ground.

In all, fifty-eight batches of root cuttings were prepared, comprising over fifteen hundred cuttings of each of the main varieties. The batches were divided into 128 groups, 58 of which were inserted in Environment A, 24 in B and 46 in C.

Recording and subsequent treatment.

Cuttings were labelled individually and the date when each new shoot appeared above ground recorded, together with data about its subsequent behaviour.

Finally, when the plants in a group were established and growing strongly and some weeks had elapsed since the appearance of the last new shoot in that group, most of the plants were lifted, washed and the number and position of shoots and new roots recorded. A few plants were left to grow *in situ* or replanted for further observation.

Results of experiments.

Effect of season.

The most striking result has plainly been the seasonal response. Although active healthy roots, well-furnished with buds and apparently ideal propagating material, can be dug at all times of the year and made into root cuttings, they are very unlikely to grow in May, June and July, have a rather better chance of success in April, August or September, but are very likely to grow from October to March. It thus appears that there are distinct " off ", " intermediate " and " on " seasons for propagation of raspberries from root cuttings (see Table I).

TABLE I.

*Effect of season on regeneration of raspberry root cuttings. Summary of results of all experiments from 1949–1952.**

Month when roots were dug and cuttings inserted	var. Lloyd George			var. Malling Promise		
	Total number cuttings	No. of groups	% which grew	Total number cuttings	No. of groups	% which grew
July	18	1	0	16	1	0
August	87	4	2	91	4	5
September	209	8	7	187	8	16
October	205	8	45	209	8	53
November	81	3	51	176	4	70
December	143	6	41	146	6	63
January	111	4	60	101	4	71
February	188	8	57	133	6	73
March	219	9	49	310	11	62
April	128	5	32	152	6	31
May	81	3	2	81	3	2
June	88	4	0	88	4	1
Total	1,558	63	—	1,690	65	—

* The numerical data have been subjected to statistical analysis and only those differences that are clearly significant are discussed in detail in the text.

Effect of environment.

Although it proved practicable to propagate raspberries under all three environmental conditions, there were marked differences in the speed with which new shoots were produced and in their subsequent performance under different conditions.

A. *Cool glasshouse.* Root cuttings inserted in the glasshouse from late August to early April commenced to produce shoots within a few weeks, most of them appearing above ground between 1 and 7 weeks after insertion of the cutting. Some of the shoots made little progress and ultimately died but the others produced rosettes of leaves just above ground level and later elongated into new canes. In cuttings inserted from early March onwards, production of a rosette was followed at once by elongation of the shoot but, in cuttings propagated from August to February, shoots remained in the rosette stage from the time of their emergence until March or April before elongating.

The proportion of successes in the glasshouse was low when cuttings were planted in the late summer, rising to a peak in the new year and then falling off rapidly (see Fig. 4(*a*)).

New shoots made under glass do not usually transplant well until each has developed at least a few roots from its stem-base (i.e. between soil level and the point of origin of the stem from the cutting) but if left too long they suffer a severe check on transplanting. Propagation under glass has thus to be timed so that by planting time the cuttings have produced new shoots, not yet too large and each with its own root system. The best time to propagate is probably in February or early March, when plants should be suitable for planting out of doors by the end of April or early in May, at a time when they will grow away with the minimum of check.

B. *Cold frames.* Some of the cuttings inserted in cold frames in September and October produced new shoots within a few weeks but others did not do so until the following spring. Cuttings put in after October remained dormant and did not produce any new shoots until after the beginning of March. Those inserted in November and December made stronger growth than those planted earlier and were ready for transplanting towards the middle and end of April respectively.

Rather few groups have been propagated in cold frames but results suggest that, where frames are used, cuttings should be inserted between November and February. Earlier planting may result in fewer successes (see Fig. 4(b)) whilst later cuttings may produce less new plants which, moreover, grow too late for satisfactory transplanting to the open.

C. *Out-of-doors.* The few cuttings which grew when inserted out-of-doors in August produced new shoots within one month. Cuttings set out in September or October sometimes produced shoots before January but normally no shoots appeared above ground until the spring. When roots were inserted after the beginning of November they always remained dormant until the spring and produced most of their new shoots in a flush from March onwards, the date depending on when the cuttings were planted.

Although some success has been obtained in all months from September to February, the results suggest strongly that, out-of-doors, it is best to plant roots in November (see Fig. 4(c)).

New shoots developed more slowly from roots planted in the open than in cold frames and were not suitable for transplanting until mid-May, even from October-inserted roots, whilst roots planted in February, March and April were not ready for transplanting until late May, early and mid-June respectively, which may coincide with bad transplanting weather. On the other hand, plants left to grow *in situ* became well-established in the first year. There are thus great advantages in planting the cuttings direct into their permanent positions to avoid the need for transplanting. However, gaps will be left wherever root cuttings fail to grow and gappy rows are undesirable. It is therefore advisable to plant a reserve bed from which gaps in the permanent rows can be filled in May.

Conclusions on environmental effects.

Several interesting points emerge from the data, as illustrated in Fig. 4.

During the " off " and "intermediate" seasons, cuttings are much more likely to regenerate in the warmest environment (A) even though only a small proportion do so.

During the " on " season from October to March, the proportion of successes in (A), in the glasshouse, tends to rise to a well-defined peak in the months of January, February and March. On the other hand in (C), in the open ground, the peak is reached much earlier, soon after the beginning of the " on " season, after which the proportion of successes falls off steadily. (B), in cold frames, provides a microclimate intermediate between a heated glasshouse and the open ground and cuttings in this environment behave in an intermediate way, showing a high proportion of successes for a longer period of time than in either of the other environments.

For the variety Lloyd George the best results seem to be produced by inserting the cuttings in a glasshouse or cold frame, at the appropriate season. The pro-

PLATE I

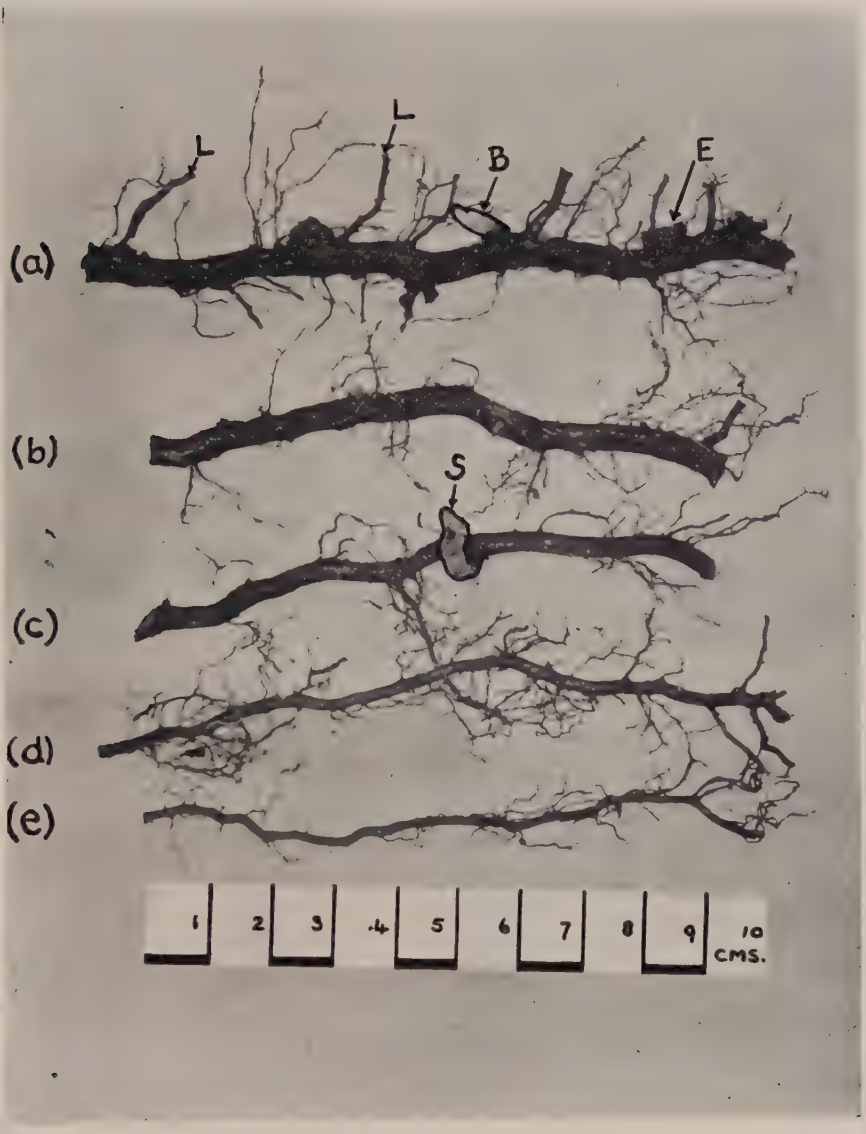

Fig. 1.

Root cuttings prepared for propagation. Long lateral roots have been trimmed (L) but fibrous rootlets are left. Sturdy buds (B) are not removed but shoots longer than (S) are very brittle and usually damaged, in which case they are best removed (E).

[face p. 32

portion of plants that grow in the open ground may be rather lower, even though they are put in at the most suitable time. On the other hand, Malling Promise can be propagated with equal success in any of the three environments, provided the cuttings are taken at the proper season.

Therefore, within the " on " period, the optimum date for propagation depends both on the variety and the nature of the environment into which the root cuttings are to be put to grow.

Effect of age.

Comparable batches of cuttings of different ages showed no significant differences in the regeneration of roots dug from a few months up to about 2½ years after the parent plants were planted.

Effect of size and type.

Where root cuttings are to be used to get the maximum number of new plants, it will be necessary to discard those parts (if any) of the roots which will not regenerate and then divide the rest into the smallest pieces which are both convenient and viable.

An analysis has been made, in a number of batches, of the effects on regeneration of various cutting characteristics.

Most of the root cuttings were made about 10 cm. long and relatively few experiments have been made to assess the effect of *length* on the viability of root cuttings. These have shown, however, that pieces as short as 5 cm. can be used if material is scarce but with less chance of individual success. Further work is proceeding on this problem.

In a sample of 838 cuttings, mainly about 10 cm. long, there was no significant difference in the proportion of successes between roots that varied in average *thickness* from one to five millimetres. Roots less than one millimetre thick make poor propagating material and have not produced enough new plants in the few instances where they were used.

Almost all the roots of Lloyd George have had at least a few buds per 10 cm. and many have had several. Results from the few roots which had no *visible buds* show that such roots can regenerate, although not as readily as those showing buds at the time of planting. About a quarter of the cuttings of Malling Promise had no visible buds, but more than half of these produced new plants. Thus it would be wasteful of propagating material to discard bud-less roots of either variety and it is recommended that otherwise suitable pieces should be used, irrespective of whether or not buds can be seen.

Some roots are much more heavily furnished with *lateral roots and rootlets* than others, but lateral roots were only reduced where they inconvenienced planting. On a sample of 800 cuttings those with most root showed highest regeneration rates and it therefore seems prudent not to remove more lateral roots than necessary.

Stages in regeneration.

The regeneration of cuttings and their subsequent growth present several features of interest, which are summarized below.

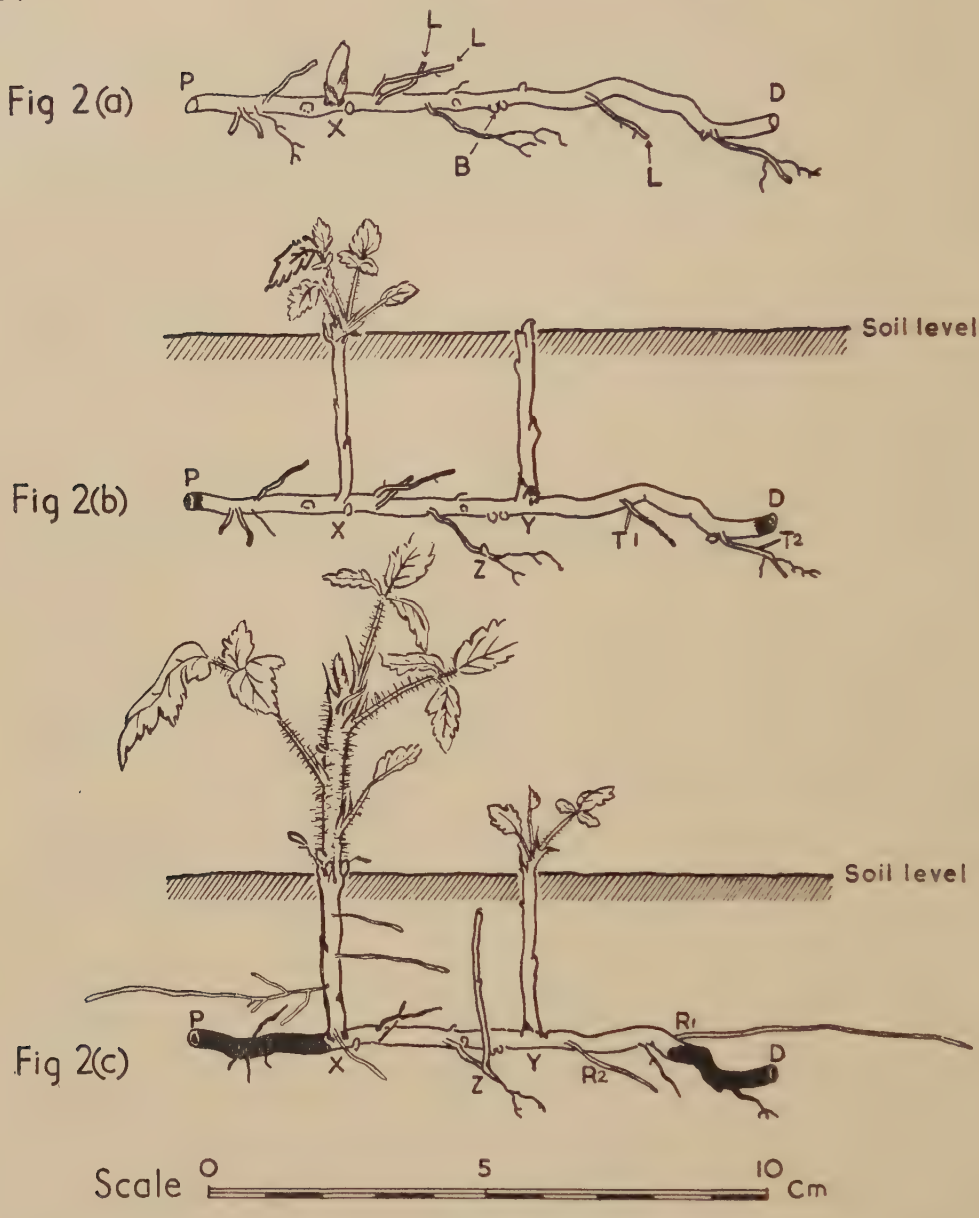

FIG. 2.

Stages in regeneration of a cutting grown in glasshouse, showing development of buds into root suckers. (*a*) Cutting as planted, with elongating bud (X), and several small buds (B). (26th October, 1951.) (*b*) A shoot has grown from (X) and formed a rosette of leaves; shoot (Y) is just breaking through ground; ends of original root starting to die but two weak new roots (T1 and T2), had grown from lateral roots. (*c*) Shoot (X) elongating and producing stem-roots; shoot (Y) has rosette but no roots; shoot (Z) growing from lateral root still subterranean; strong roots (R1 and R2) growing from parent cutting; temporary roots (T1 and T2) now dead; parent root dead from proximal end (P) to first shoot (X) and from distal end (D) to the most distal new root((R1). 22nd March, 1952.)

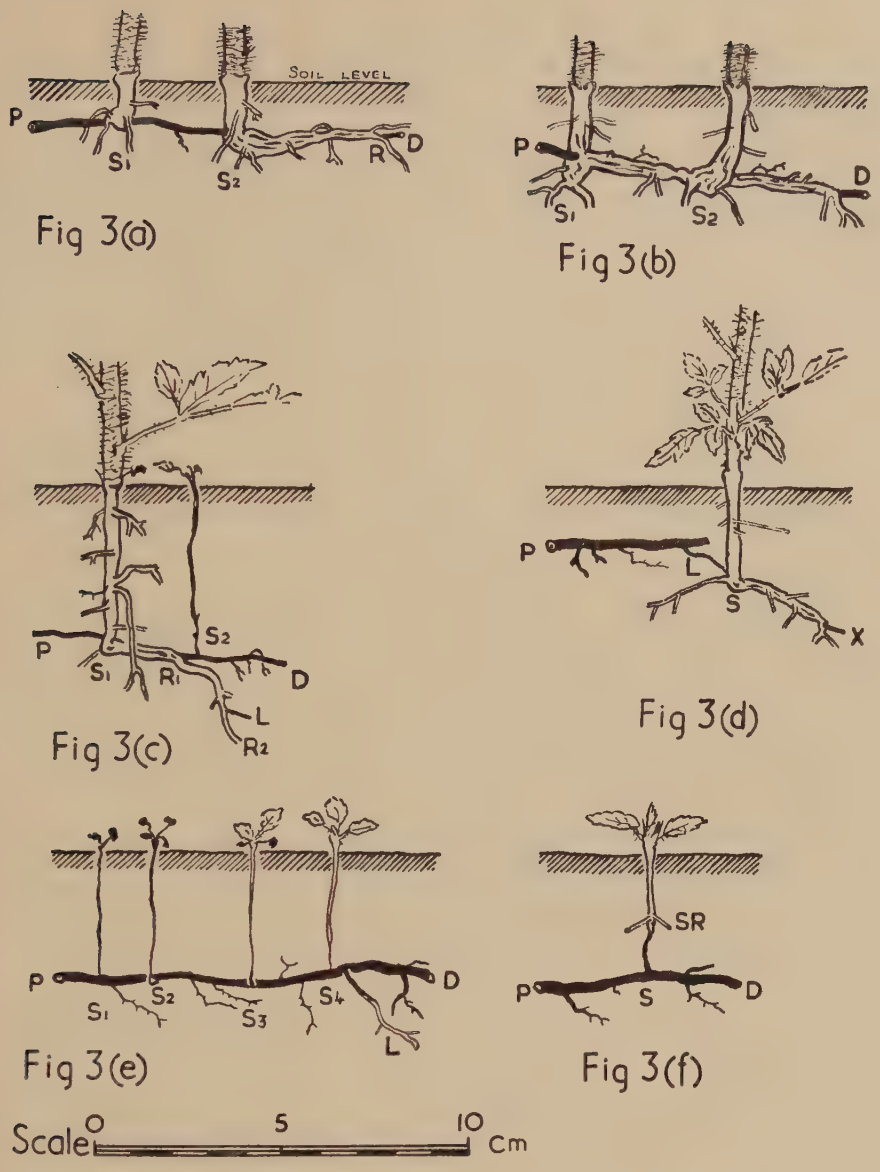

FIG. 3.

Common polarity phenomena in cuttings: (*a*) Cuttings with two established shoots one of which (S1) has not incorporated any of the parent root, and is detachable by pulling gently. S2 incorporates part of the parent (S2–R) which is thickening strongly and shows striae; (*b*) two new shoots with most of parent still alive except for proximal and distal ends; (*c*) shoot S1 established and growing strongly with several stem roots, but shoot S2 dead together with the distal end of the parent root; the main new root S1–R1–R2 incorporates part of an existing lateral, the dead tip of which is shown at L; (*d*) parent root has died except for part of a lateral from which a strong shoot is growing; (*e*) four shoots grew from the parent root but all have started to die from their bases; S1 and S2 are dead; outer leaves and most of stem-base of S3 are shrivelling; leaves of S4 are still alive but the stem-base is dead; S4 could still recover (see *f*). All parent root is dead except for the distal part of one lateral root (L) which has two feeble rootlets but would die in time; (*f*) shoot with a dead base sometimes produces stem roots (SR); such shoots often survive, but grow very slowly at first.

P=proximal end of root. D=Distal end.

Dead parts of parent root cutting are shown in solid black.

Sequence of development.

To become established, each root cutting must obviously produce one or more new shoots and a system of new roots. Several hundreds of the cuttings were inspected during regeneration and usually no new roots were observed until after a new shoot had elongated from the root cutting, broken through the surface of the soil and developed green leaves. Where cuttings had made new root growth before a shoot had appeared above ground, the roots were thin, feeble, few in number and probably short-lived. The evidence suggests that growth of green leaves on at least one shoot is normally necessary before an active new root system can be formed.

Polarity of cuttings.

The cut ends of raspberry root cuttings do not callus over, nor are new shoots and roots confined mainly to the proximal and distal ends of the cuttings respectively, as in some other forms of propagation by root cutting (e.g. *Papaver orientale* L.). A degree of polarity is nevertheless exhibited.

When planted, cuttings may bear buds in all stages of growth from very small, barely visible primordia to elongating buds several millimetres long. Where cuttings are furnished along their length with a number of similar buds there is a tendency for one or more of the buds towards the proximal end to develop into shoots. On the other hand, where one of the buds is more highly developed than others at planting time, that bud is most likely to grow into a shoot, wherever it may be located and for this reason new shoots often grow from the median or distal positions on cuttings. Various relationships that can exist between the new plant and original cutting are illustrated in Fig. 3.

When a raspberry root fails to regenerate, the thicker roots usually die more quickly than thin ones. Even where the main root dies, shoots occasionally grow from lateral roots and the thinnest raspberry root in which secondary thickening has occurred appears to be capable of producing a new plant under favourable conditions (Fig. 3(d)).

Polarity was more marked in the development of new roots, which show a tendency to occur near the distal end of the parent roots. Strong new root systems often develop from lateral roots as well as (or instead of) from the main root of the cutting (Fig. 3(c)). New roots may arise at any distance behind the severed end of a main or lateral root and part of the original cutting often becomes incorporated into the new plant (Figs. 3(a), (b) and (c)) accompanied by active thickening between the point of attachment of the new shoot and the most distal strong new root. Clearly-marked longitudinal striations on the bark show which parts of the root are active. Parts of the parent root lying outside this active region become moribund, and ultimately die after a few weeks or months.

The direction of cambial flow appears to be morphologically downwards in the shoot and acropetal in the root, as in a species of poplar with rather similar habits of sucker growth described by Brown (1936).

Production and survival of shoots.

Nearly half of the cuttings which grew produced one new shoot each, about a third produced two new shoots, and diminishing proportions three, four, five and

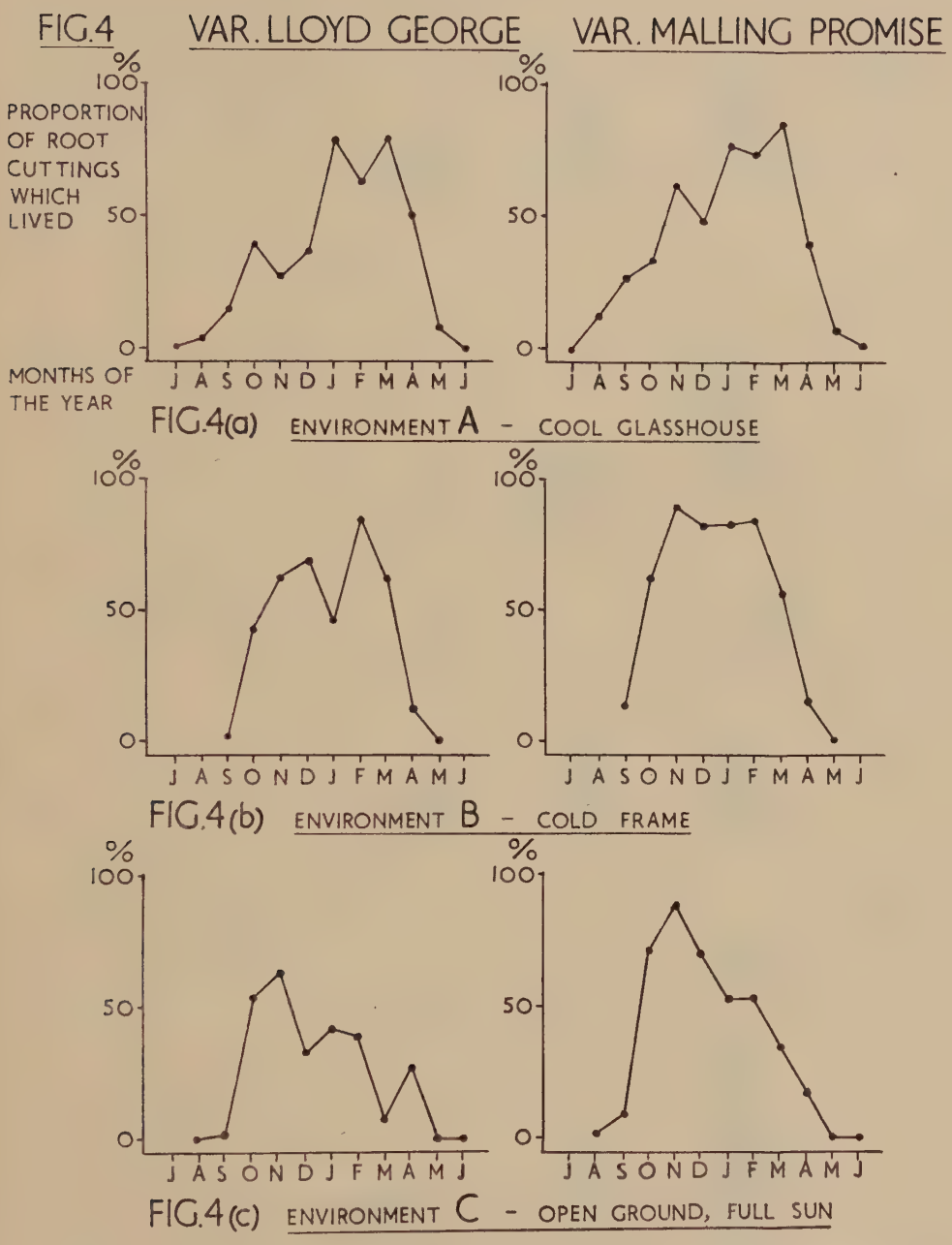
FIG.4
VAR. LLOYD GEORGE
VAR. MALLING PROMISE
%
100
50
0
PROPORTION OF ROOT CUTTINGS WHICH LIVED
MONTHS OF THE YEAR
J A S O N D J F M A M J
FIG.4(a) ENVIRONMENT A - COOL GLASSHOUSE
FIG.4(b) ENVIRONMENT B - COLD FRAME
FIG.4(c) ENVIRONMENT C - OPEN GROUND, FULL SUN

Fig. 4.

Diagram showing the proportion of cuttings which regenerated in the various environments, based on all experiments from 1949–1952. (See Table I.)

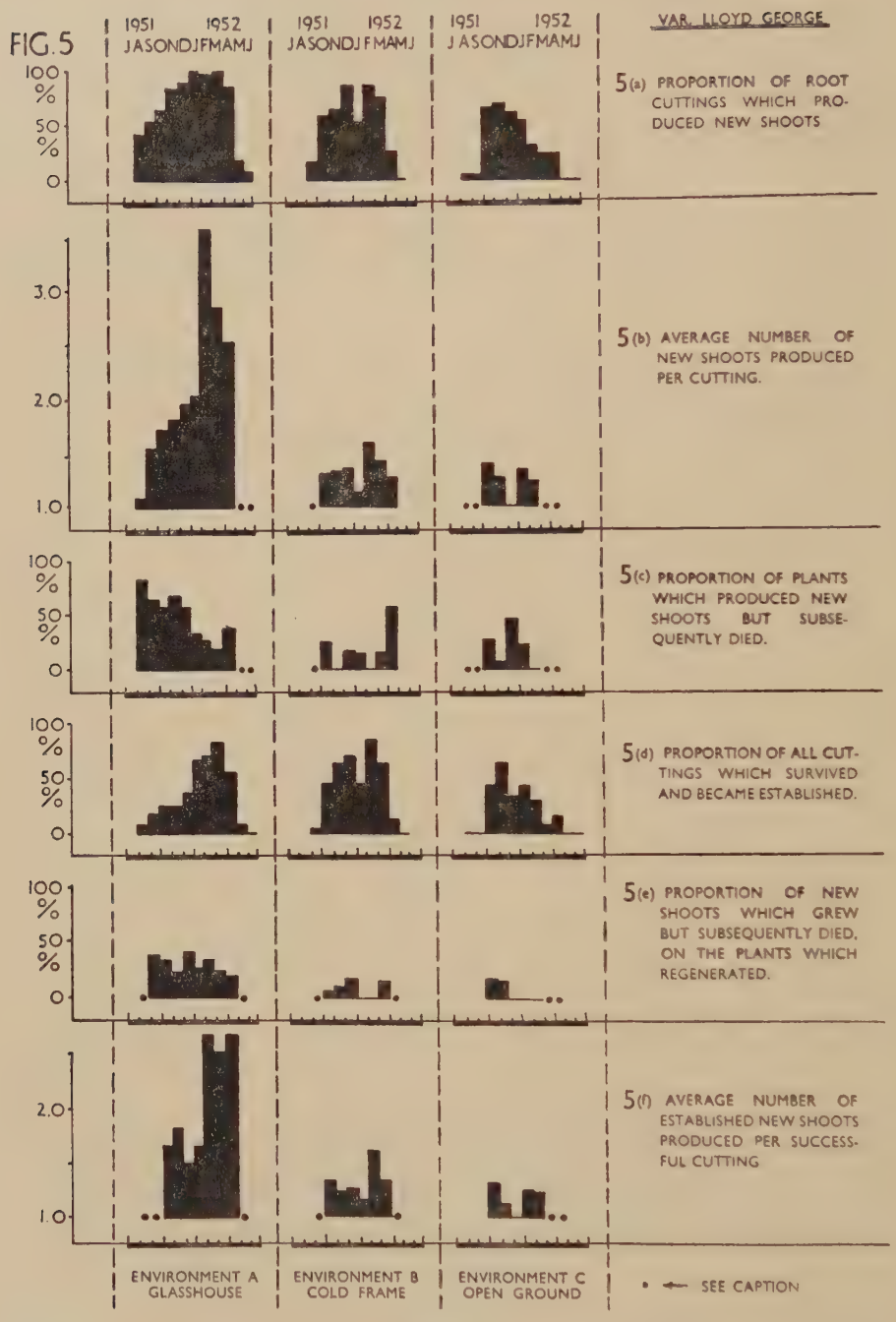
FIG. 5
1951 1952
J A S O N D J F M A M J
VAR. LLOYD GEORGE
100 %
50 %
0
5(a) PROPORTION OF ROOT CUTTINGS WHICH PRODUCED NEW SHOOTS
3.0
2.0
1.0
5(b) AVERAGE NUMBER OF NEW SHOOTS PRODUCED PER CUTTING.
5(c) PROPORTION OF PLANTS WHICH PRODUCED NEW SHOOTS BUT SUBSEQUENTLY DIED.
5(d) PROPORTION OF ALL CUTTINGS WHICH SURVIVED AND BECAME ESTABLISHED.
5(e) PROPORTION OF NEW SHOOTS WHICH GREW BUT SUBSEQUENTLY DIED, ON THE PLANTS WHICH REGENERATED.
5(f) AVERAGE NUMBER OF ESTABLISHED NEW SHOOTS PRODUCED PER SUCCESSFUL CUTTING
ENVIRONMENT A GLASSHOUSE
ENVIRONMENT B COLD FRAME
ENVIRONMENT C OPEN GROUND
• ← SEE CAPTION

FIG. 5

Histograms illustrating the behaviour of 1080 cuttings propagated from August 1951 to June 1952. Variety Lloyd George. (• = ratio based on fraction where denominator < 7).

six new shoots respectively. In many cases one or more of the shoots died subsequently but 56% of the established plants had one permanent shoot each, 28% had two, 12% three, 3% four and 1% five permanent shoots (i.e. shoots each with its own active root system).

Both the number of new shoots which grow from any particular root cutting and the number which ultimately survive, appear to depend upon a combination of factors of which season, environment, and the size of the cutting are probably most important.

In any particular environment, comparable cuttings tend to produce most shoots each at the season when the cuttings themselves have the greatest chance of survival (Figs. 5 and 6, cf. (b) and (d) respectively). In the glasshouse a much higher average number of shoots is produced than in the frame or open ground (Figs. 5(b) and 6(b)), and, although these have a higher mortality, (5(e) and 6 (e)), yet the number of surviving and established shoots per cutting has been highest in the glasshouse and lowest out-of-doors throughout, with plants in the cold frame in an intermediate position (Figs. 5(f) and 6(f)).

The rosettes produced at ground level (Fig. 2) consist of three to five leaves, in the axils of which develop the basal buds that normally give rise to the following year's new canes. In the experiments under glass the rosette leaves produced in the winter often became silver-coloured although they normally recovered later. No explanation of the phenomenon can be advanced at present.

Cuttings 8 to 12 cm. long seem more likely to produce two or more new shoots each than do shorter ones. Plants with two shoots may become established more rapidly than those with only one, and it is at present recommended to cut roots into 8 to 12 cm. pieces; but further experience may suggest regulating the size of the root cutting according to the season and environment in which it is to be propagated.

Mortality of roots and shoots.

During the development of the rosette of leaves, about three-quarters of the cuttings produced strong systems of new, active roots but about a quarter failed to become established and died. In the latter, the shoots at first developed apparently normal rosettes, of which the outer leaves later became water-soaked and died. At that stage the base of the stem of each shoot had usually rotted where it was attached to the parent root. Generally such shoots ultimately withered and died but a few recovered after producing new roots above the basal rotted area (Fig. 3(e) and (f)), although these were slow to develop into established plants.

Cuttings planted in the open ground in autumn are liable to damage from frost-heave if new shoots grow to the surface and form rosettes of leaves before the onset of winter. Shoots may be pulled bodily from their parent roots and die subsequently.

Division of established root cuttings.

Root cuttings which produce two or more strong new shoots can be divided if so desired. They should not be lifted for division until the main shoots are several cm. long and elongating strongly, by which time each will usually have its own system of stem-roots, but lifting should not be delayed after that time because the shoots rapidly become too large to transplant well.

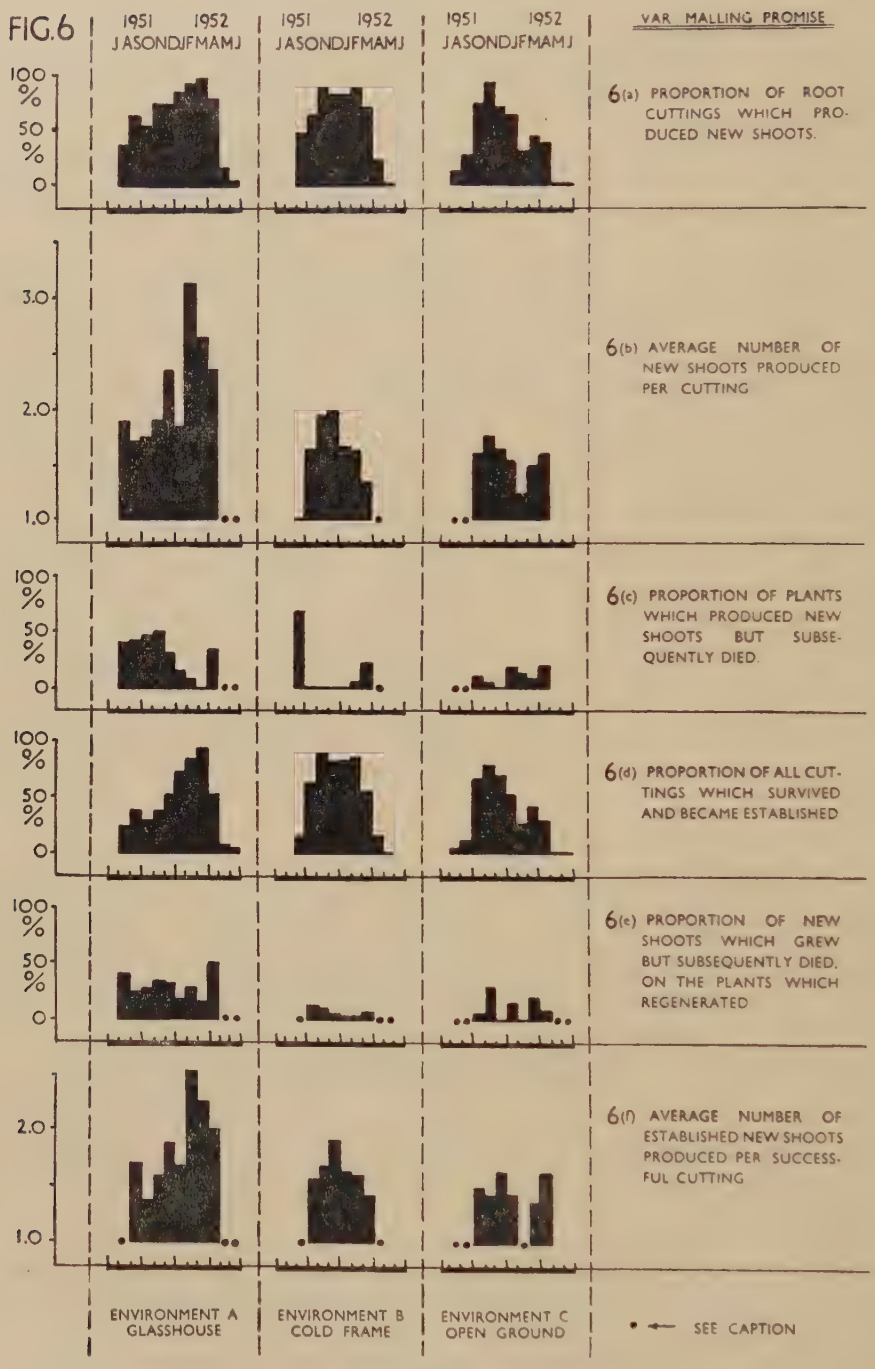
FIG.6
1951 1952
J A S O N D J F M A M J
VAR MALLING PROMISE
100 %
50 %
0
6(a) PROPORTION OF ROOT CUTTINGS WHICH PRODUCED NEW SHOOTS.
3.0
2.0
1.0
6(b) AVERAGE NUMBER OF NEW SHOOTS PRODUCED PER CUTTING
6(c) PROPORTION OF PLANTS WHICH PRODUCED NEW SHOOTS BUT SUBSEQUENTLY DIED.
6(d) PROPORTION OF ALL CUTTINGS WHICH SURVIVED AND BECAME ESTABLISHED
6(e) PROPORTION OF NEW SHOOTS WHICH GREW BUT SUBSEQUENTLY DIED, ON THE PLANTS WHICH REGENERATED
6(f) AVERAGE NUMBER OF ESTABLISHED NEW SHOOTS PRODUCED PER SUCCESSFUL CUTTING
ENVIRONMENT A GLASSHOUSE
ENVIRONMENT B COLD FRAME
ENVIRONMENT C OPEN GROUND
• ← SEE CAPTION

FIG. 6

Histograms illustrating the behaviour of 1080 cuttings propagated from August 1951 to June 1952. Variety Malling Promise. (• = ratio based on fraction where denominator < 7).

When dividing a cutting, all but one of the rooted shoots should be detached by pulling gently sideways, but the weakest one should be left attached to the parent root and replanted with it, since the latter appears to be incapable of producing further new shoots.

SUBSEQUENT GROWTH OF PLANTS.

Plants from cuttings have been transplanted into fruiting beds (when propagated in frames or boxes) or left to grow *in situ* (when planted in the open ground). Provided conditions are suitable, they grow well and make moderately strong new canes and root systems in the first season. By the second season each becomes a mature plant with normal shoot and root systems.

YIELD OF ROOT CUTTINGS.

In fertile soil, raspberries will normally produce sufficient roots by the first winter after planting to make it worth-while to lift them for propagation by root cuttings. On the other hand, where plants do not make strong growth in their first season, because of late planting, adverse weather, or for any other reason, it is probably best to delay lifting until the second winter after planting, by which time a prolific supply of roots should have been produced.

Counts of root cuttings, made from roots dug from forty separate sample areas of one square yard each, indicate that yields of from $\frac{1}{4}$ to $\frac{1}{2}$ million root cuttings per acre can be expected after one to two seasons of growth, from plants set out up to six feet apart each way.

DISCUSSION.

The regeneration of raspberry root cuttings presents several features of interest. Any particular cutting may behave in one of three ways, viz: die without any apparent attempt to regenerate; produce one or more new shoots and/or feeble short-lived new rootlets, but subsequently die; or succeed in regenerating by producing one or more new shoots and a strong new root system.

The capacity of root cuttings to grow is at its lowest ebb in an " off " season from May to July, when most roots fail to make either new shoots or roots and die without any apparent attempt to regenerate. The " off " season is followed by a short " intermediate " season, during which the capacity of roots to grow rapidly increases to reach a maximum in an " on " season which extends from October to March. This in turn is followed by a short " intermediate " season during which capacity to grow steadily diminishes until the onset of the " off " season.

Although the *capacity* of cuttings to grow appears to be dependent mainly on the condition of the parent plant at the moment when the root is severed, the *actual performance* of cuttings during the " on " season depends upon other factors including size of root and the relationship between season and environment. The effects of these factors are complex. The interval between planting and appearance of the first shoot varies from a few days to more than six months, depending upon season and environment. Roots planted out-of-doors in September sometimes do not produce shoots until the following April, whereas roots propagated in the glasshouse

produce shoots much more quickly. New shoots are produced in greatest numbers by cuttings propagated in a heated glasshouse in the late winter months.

Even where cuttings produce new shoots, some or all of these may die whilst still in the rosette stage and, of course, a cutting only regenerates successfully if one or more of its new shoots becomes established and forms a new root system. Although cuttings taken in the " on " season have a high capacity for regeneration, the proportion which actually does so varies with environmental conditions.

Cuttings taken in October or November appear more likely to grow if given natural winter temperatures by planting out-of-doors, whereas those taken from December to February respond better if put in a cold frame ; from March to the end of the " on " season, the highest proportion of successes comes from cuttings put in a heated glasshouse. Thus, the later cuttings are taken in the " on " period, the warmer must be the environment to promote growth and regeneration. It is interesting to find that these results confirm the horticultural belief that root cuttings propagated in the open ground should be planted early in the winter.

GENERAL CONCLUSIONS.

Root cuttings can be used for propagating Lloyd George and Malling Promise raspberries and probably most other varieties and provide a method of multiplying stocks at least one hundred-fold after one year's growth under favourable conditions. The method may be of use to breeders and research workers but may also have more general application in varieties that naturally produce few root suckers.

The following recommendations seem justified :

Choice and preparation of material.

Roots should preferably be taken from plants not more than 2 years old.

Dig or fork roots out and wash if necessary.

Cut into pieces 8–12 cm. long, using all healthy roots from 1–5 mm. in diameter.

Do not remove buds or elongating shoots unless they are badly damaged.

Lateral roots and fibrous rootlets should be left unless too long for convenience of planting, in which case shorten back to 2–3 cm.

Environment for propagating.

Cuttings may be planted out direct into the open ground or grown in beds or boxes under glass and later planted out-of-doors. The former method is cheapest and has many advantages. With some varieties a rather higher yield of new plants may be obtained by propagating under glass but the method involves more labour.

When propagating in a cool glasshouse, cuttings should not be taken until February or early March or the new plants will be too forward by April or early May, which is the best time for setting them out from under glass into the open. In cold frames, cuttings may be planted at any time between November and February, and transplanted to the open in late April. Planting direct into the open ground is probably best done in November, at the same time planting a reserve bed from which plants can be transplanted in May to fill gaps in the permanent rows.

ACKNOWLEDGMENTS.

Thanks are due to Ir. J. Floor of the Instituut voor de Veredeling van Tuinbouwgewassen, Wageningen, for kindly supplying a copy of Jansen's article and to Mr. W. G. C. Krause, for translating it. Gratitude is also expressed for the help given by various present and former members of the staff of the Department, particularly Mr. R. F. Beeston, in growing and recording the large number of plants involved in these experiments.

REFERENCES.

Brown, A. B. (1936). Cambial activity in poplar with particular reference to polarity phenomena. Canad, J. Res., **14**, 74–88.

Butterfield, H. M. (1947). Bush berry culture in California. Calif. Agric. Ext. Serv. Circ., 80.

Darrow, G. M., and *Waldo, G. F.* (1948). Raspberry culture. Fmrs' Bull. 887 U.S. Dep. Agric. (rev. 1948).

Grubb, N. H. and *Harris, R. V.* (1945). The planting and maintenance of raspberry cane nurseries. Rep. E. Malling Res. Sta. for 1944, 109–13.

Hedrick, U. P. (1925). The small fruits of New York. Lyon, Albany.

Hudson, J. P. (1950). New Zealand roots grow well here. The Grower **34** : 4, 159–60.

Jansen, A. (1952). Het opkweken van Frambozenplanten. De Boomkwekerij, 9 Mei 1952, 101–02.

Kains, M. C., and *McQuesten, L. M.* (1945). Propagation of plants. Orange Judd, New York.

Potter, J. M. S. (1936). Propagation of blackberries. J. R. hort. Soc., **61**, 437–8.

Swartwout, H. G., and *Martin, W. R.* (*Jnr.*) (1942). Growing raspberries and blackberries. Missouri agric. Expt. Sta. Bull. 450.

Wood, C. A. (1949). Raspberry cane nurseries. Rep. E. Malling Res. Sta. for 1948, 141–47.

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VIRUS DISEASES OF CHERRY TREES IN ENGLAND

I. SURVEY OF DISEASES PRESENT

By A. F. POSNETTE
East Malling Research Station, Kent

CONSIDERABLE attention has been paid recently to virus diseases of cherries in European countries but, in contrast to the extensive American literature, relatively few reports have been published. Blumer and Meyer (1947) and Stoll (1951, 1952) described the symptoms and transmission in Switzerland of a virus disease called "Pfeffingerkrankheit" which resembles the rasp leaf disease of North American workers; Kotte (1951) and Mulder (1951) described similar diseases in Germany and Holland respectively. Willison (1950) reported some field observations on virus-like symptoms on cherries in Southern England.

The survey here described has not been comprehensive, and no organized inspection of all orchards in sample districts or of a random sample of orchards in different districts has yet been attempted. The orchards on the Research Station and four cherry orchards in different parts of Kent have been surveyed and the distribution of trees with virus symptoms mapped; but most of the information has come from visits to orchards where suspected virus symptoms were reported by the National Agricultural Advisory Service officers or by growers. During 1950 and 1951, over fifty orchards in Kent, Herefordshire and Worcestershire were inspected and bud-wood was collected from any trees with virus-like symptoms, unless these were already represented in the collection started in 1949 at East Malling Research Station. This virus collection was maintained in the mazzard (*Prunus avium*) clone, F12/1, widely used as a rootstock, plants of which were inoculated by means of bark grafts. All tests made so far indicate that the Malling stock of this clone is virus-free.

In addition to this study of visible symptoms in orchards, a survey of a different nature was carried out in the course of indexing (testing for virus) potential stock trees of important commercial varieties in order to find virus-free material for propagation. This method of surveying by indexing symptomless trees has disclosed a number of latent viruses whose effects on yield, vigour and stock-scion compatibility have not yet been investigated. The following is intended as an introduction to subsequent accounts of investigations on the diseases here described.

RESULTS FROM VISUAL SURVEY.

VIRUS SYMPTOMS.

The symptoms which have been seen in orchards, and the virus nature of which has been confirmed by graft-transmission, can be arranged in six groups.

Group 1. Rosette.

The characteristic symptom is a shortening of the internodes so that the leaves are borne in close whorls. The type virus in this group was found in the variety Schrecken, infected trees of which bear harsh, narrow leaves with pronounced

crinkling on either side of the midrib, and vein clearing that develops later into a mottle (Fig. 1). All these symptoms were repeated on the clonal mazzard, F12/1, in the year after graft-inoculation, but other cherry varieties have not yet developed the complete symptom picture. Vein clearing without rosette developed in Merton Heart, while rosette symptoms without vein clearing have been seen on orchard trees of Waterloo and French Black.

The rosette virus retarded the growth of young Schrecken trees considerably, but the degree of stunting varied from year to year and was more pronounced on early growth than on that occurring late in the summer. Symptoms on orchard trees were often restricted to a few branches in one year and did not appear in the next, so that one cannot be certain that symptomless trees are not infected unless transmission tests are made. When the 1946–51 yields of trees showing symptoms in 1951 were compared with those of symptomless trees a significant reduction in total yield of only 32·4 lb. per tree was found to occur. As tests have shown that some of the symptomless trees are infected, the effect of the virus is probably greater than this comparison indicates, assuming that yield is reduced even when symptoms are not apparent.

Group 2. Rasp leaf.

Viruses in this group also cause rosetting and harsh, narrow leaves but differ from those in group 1 in causing enations between the primary veins on the underside of the leaves (Fig. 2). There are considerable varietal differences in the development of these enations, and the possibility of some of this variation being due to virus-strain differences is being investigated. Well developed enations and narrow leaves have been seen on Frogmore, Roundel and Napoleon, whereas Emperor Francis B,* Chesley Tartarian and Guigne d'Annonay have been seen with only sparse enations and little or no leaf deformation. No enations have been seen on Early Rivers, and infection tests have shown that this variety can behave as a symptomless carrier. Rasp leaf has a severe stunting effect on many commercial varieties, however, and most affected orchard trees seen by the writer had died back to the main branches and were commercially useless.

The rasp leaf virus has been transmitted from Frogmore to Bing with full symptom development and large enations also appeared on Morello seedlings after inoculation, but few of the F12/1 plants inoculated have developed enations and these were inconspicuous. Although markedly stunted and producing some coarse narrow leaves, F12/1 is not a good indicator for the rasp leaf virus.

Group 3. Tatter leaf.

The term "tatter leaf" has been adopted to describe a disease characterized by large necrotic areas (as distinct from scattered necrotic spots) on the leaves, followed by the dropping out of the dead areas (Fig. 3). Several viruses or strains cause symptoms fitting this description and their differentiation has caused some difficulty. Experiments indicate that three diseases can be distinguished according to whether necrosis occurs mainly on

(a) leaves formed in the spring (i.e. the spur leaves and basal leaves on the extension growth).

* The nomenclature of cherry varieties used here follows that of Grubb (1949).

(b) leaves formed in the summer (i.e. the youngest leaves on the extension growth),

(c) both old and young leaves.

In types (b) and (c), the necrosis in the young leaves often coincides with a line pattern (Fig. 4) ; type (c) may be caused by dual infection with viruses causing (a) and (b).

Observations suggest that different tatter leaf viruses can be distinguished also by the sequence of symptoms over several years, symptoms recurring each year on some trees while others suffer a shock effect one year and are almost symptomless in subsequent years.

Trees with symptoms of acute tatter leaf appeared to carry less fruit than symptomless trees. Trees known to have been infected for several years and showing only the symptoms of the milder chronic disease appeared to carry a fair crop. Some growers have expressed the opinion that the yield of infected trees progressively declines but, owing to the practice of selling fruit on the trees, no crop weights are available to substantiate this.

The first transmissions of tatter leaf virus were made from an Early Rivers tree with pronounced type (a) symptoms and from an adjacent symptomless Kentish Red (*P. cerasus*) tree. Both types of inoculum caused severe necrosis on the F12/1 test plants in the following year and when returned to Early Rivers, both caused tatter leaf. Indexing on peach and sour cherry showed, however, that the viruses were not identical, the most probable explanation being that Kentish Red has both the tatter leaf and an additional virus.

Group 4. Chlorotic mottles.

This group can be divided into ring mottles (Fig. 5), vein banding, and " watermark " or " oak-leaf " patterns (Fig. 6), but no clear distinction between these types has yet emerged from transmission studies, and it seems probable that variations in symptoms may be due to differences in the stage reached in the development of the leaf at the time of invasion by the virus, although some characters, such as the average size of the rings, seem to be influenced by the virus strain transmitted.

Mottle symptoms were seen on many orchard trees, but latent infection was also common and symptoms developed on F12/1 plants inoculated from symptomless trees. On mature trees, mottle was often confined to a few shaded leaves and did not appear every year. For instance, Merton 42 in the Malling collection was symptomless in 1949, had a conspicuous ring mottle in 1950 and was again symptomless in 1951. Possibly the tree became infected in 1949 and showed shock symptoms in 1950 of a virus which is usually masked in the chronic phase, but it seems more probable that symptom expression is spasmodic and influenced by temperature.

Ring mottles seem to have little effect on the vigour and yield of most varieties. Observations suggest that they do reduce growth slightly in the nursery, however, and their cumulative effect over several years may delay cropping.

Two trees of Early Rivers were found with a type of mottle in which the pattern of bands and rings was composed of cleared veinlets (Fig. 7) ; leaf size was reduced and the trees were unthrifty. Transmission tests have confirmed that this virus is distinct from that causing the prevalent diffuse ring mottles on Early Rivers.

Group 5. Rusty mottle.

Symptoms of rusty mottle usually develop later in the summer than do those of other cherry viruses ; yellow spots, composed of clusters of yellow veinlets (Fig. 8) appear in July and gradually increase in intensity through August and September. Varying amounts of rusty red pigment, according to the virus strain present, develop apparently on the surface of the leaf, usually overlying the yellow spots. The superficial appearance suggests powdery lichen growth on the cuticle. By late summer the foliage of sensitive varieties, such as mazzard F12/1, has a general yellow or rusty appearance ; many commercial varieties show no, or only slight symptoms, but few Roundel and Gaucher trees have been seen without some sign of this disease, which is probably the most common of all virus diseases on cherries in Kent. Some strains of rusty mottle have an obvious debilitating effect on certain varieties (Table I), and, although not as virulent as rasp leaf, rusty mottle probably causes a greater total loss of crop because it is so prevalent.

Group 6. Yellows.

Symptoms of sour cherry yellows—fall in June of yellow leaves with green bands along midrib and main veins—were seen on many of the sour cherry trees which occur scattered through sweet cherry orchards. Two types of yellows were also seen on sweet cherry and are now under investigation as possible virus diseases ; Early Rivers trees frequently shed many yellow leaves in June ; one Amber tree was found on which most of the leaves were greenish-yellow with a lighter yellow ring mottle in August.

Non-infectious abnormalities.

Leaf abnormalities resembling virus symptoms were commonly found in cherry trees ; they were graft-perpetuated but apparently not graft-transmissible and presumably have arisen as " bud sports ". They are mentioned here because they are frequently mistaken for virus symptoms and because, being associated with reduced cropping, they should be eliminated by the same method of bud selection used to ensure the health of stocks selected for propagation.

Crinkle leaf.

Distortion of the leaf margins, with clearing of the veinlets near irregular indentations is characteristic of this condition. In some varieties, the leaves have a silvery appearance and may be rolled upwards and droop, giving the tree a wilted appearance.

Strap leaf.

Some varieties, particularly Frogmore and Waterloo, are occasionally seen with abnormally long, narrow leaves, having irregular margins. The fruit distortion associated with this condition in North America and known as " deep suture " has not been seen here.

Variegation.

A chimaera-like white streaking was frequently found on trees of certain varieties (e.g. Mumford's, August Heart) and occasionally on trees of many other varieties.

MAPPED ORCHARDS.

Five orchards were inspected tree by tree in 1949 and symptoms recorded on spot plans so that any subsequent spread could be charted. When two of these orchards were resurveyed in 1951, the number of symptom-bearing trees had apparently increased, and only part of this increase can be attributed to a more experienced eye. Rusty mottle was not recorded, as the significance of this symptom was not appreciated until later.

Orchard 1 (East Sutton) : 250 Early Rivers trees, 20 pollinator trees of unknown variety, and 12 Kentish Red trees (*Prunus cerasus*). Two symptom types predominated—tatter leaf (mainly on spring leaves) and mottle—and the numbers of trees with each were :

	Tatter leaf ± mottle	*Mottle alone*
1949	19 or 7·6%	39 or 15·6%
1951	40 or 16·0%	37 or 14·8%

Orchard 2 (Yalding) : 200 sweet cherry trees, the majority Early Rivers, with Schrecken, Florence, Napoleon and Governor Wood also present ; there were 3 Kentish Red trees with sour cherry yellows. Tatter leaf was the main symptom-type, differing from that in orchard 1 in that the necrotic areas were darker and occurred more frequently on young leaves at the tips of extension growth (summer leaves).

	Tatter leaf ± mottle	*Mottle*
1949	8= 4%	None recorded
1951	32=16%	4=2%

Orchard 3 (Bobbing, Sittingbourne) : 90 trees of many varieties, including Napoleon, Noble, Early Rivers, Guigne d'Annonay and Amber. The predominant symptom was rasp leaf, occurring on nearly every tree, irrespective of age or variety, at one end of the orchard, a distribution suggesting tree-to-tree spread.

	Rasp leaf	*Tatter leaf*	*Mottle*
1949	31=34·4%	6=6·7%	2=2·2%

Orchard 4 (Selling) : 530 trees, the mapping of which was spread over 1949 and 1950. Mottle of the vein-banding type was the predominant symptom recorded, the variety Finn's Black showing particularly clear symptoms, but during a cursory inspection in 1952, rusty mottle was found to be prevalent. Trees of Governor Wood and Black Republican were said to have been imported from America.

	Rasp leaf	*Tatter leaf*	*Mottle*
1949/50	3=0·5%	11=2·1%	51=9·5%

Orchard 5 (East Malling Research Station) : 86 trees of each of the varieties Schrecken, Early Rivers and Turkey Heart. Most trees of the two latter varieties showed vague mottles, and the chief interest lay in the Schrecken in which indexing

had revealed the presence of the rosette virus. A tree-by-tree inspection in 1951 found 27 Schrecken trees (31%) with symptoms of rosette.

These five orchards were the first in which the particular symptom-type predominating in each was seen by the writer. Less detailed observations made in other orchards subsequently have shown that, except for the high incidence of rasp leaf in Orchard 3 and for the omission of rusty mottle records, these five orchards are not unusual as regards virus infection, but are representative of mature commercial orchards in Kent. A cursory examination of orchards in the West Midlands indicated a similar position there, as would be expected from the fact that the same nurserymen supply planting stock to both districts.

Effect on vigour.

When F12/1 mazzard plants with symptoms were compared with healthy plants two years after inoculation, it was found that both height and girth had been adversely affected by each of the three virus groups, rusty mottle, tatter leaf and rosette. Tatter leaf had the most severe effect, reducing height and girth by 25%; rosette reduced height to the same degree and girth by 19%. The prevalent rusty mottle virus had the unexpectedly large effect of 22% on girth and 15% on height (Table I).

Table I.

Effect of viruses on girth and height of mazzard F12/1 infected for two years.

	Not infected (9 trees)	Rusty mottle (7 trees)	Tatter leaf (4 trees)	Rosette (4 trees)
Mean girth (cm.)	20·3	15·5	14·8	16·4
S.E.	±0·55	±0·51	±0·77	±0·88
% reduction		22	25	19
Mean height (dm.)	32·1	27·3	24·0	24·2
S.E.	±0·89	±0·83	±1·26	±1·44
% reduction		15	25	25

All differences between infected and healthy plants are significant at the 5% level.

RESULTS FROM INDEXING.

In 1950, when symptoms on the test plants inoculated in 1949 showed clearly that several virus diseases were present in commercial cherry varieties, experiments were started to find

(a) differential indicator plants for distinguishing the different viruses,
(b) the most satisfactory technique for indexing.

It was known that an insect-proof glasshouse would be available for work in 1951, and so it was planned to compare the standard outdoor technique of summer inoculation and symptom-reading in the following year with a glasshouse method of spring inoculation and symptom-reading in the same year (Hildebrand, 1942).

Methods of inoculation.

The usual method of inoculation was by chip-budding (Garner, 1946), i.e. a slice about ¾ in. long with the lower end wedge-shaped, and including bark, cambium

and wood, was cut from an internode of a young shoot of the infector plant and inserted in the place of a similar piece cut from the test plant. The wedge held the scion in position while it was being secured with rubber tape. This method has the advantage over T–budding that it can be done successfully even when the bark will not " lift ", but T–budding was used for summer inoculation of yearling plants by shields cut from internodes.

Young seedlings too small for chip-budding were successfully inoculated by leaf implants. A flap of bark was peeled down by cutting above an axillary bud and pulling the petiole ; a strip of lamina was cut slightly smaller than the area of exposed cambium against which the strip was placed, and the flap of bark was then returned to its original position and secured with rubber tape. The bud at the tip of the flap usually grew and symptoms appeared first on this growth within three weeks of inoculation.

Indexing in the open nursery.

Comparison of peach, mahaleb and morello seedlings and mazzard F12/1.

Plants were inoculated in July or August and not cut back ; symptoms were recorded during the following two years.

Peach seedlings suffered from winter dieback (possibly caused by *Cytospora* sp.) so that only when unusually severe, could dieback be regarded with certainty as being caused by the virus inoculum. This limited the usefulness of peach as compared with mazzard and mahaleb, but nevertheless it was clear that peach is sensitive to viruses latent in some of the scions used, and this was confirmed in the glasshouse tests. Peach seedlings developed no definite symptoms when inoculated with rosette and rusty mottle viruses.

Mahaleb seedlings were good indicators of the ring mottle viruses, but of little use for differentiating between these viruses (or strains) because their only clear symptom was a ring mottle.

Morello seedlings were extremely sensitive to viruses in the tatter leaf group, developing severe leaf necrosis and dieback ; some were killed within two years of inoculation. Morello seedlings also proved valuable indicators of rasp leaf virus, as they developed characteristic leaf distortion and large enations (Fig. 9). They showed no symptoms with viruses in the mottle groups, however, and considerable variation between seedlings in vigour and leaf shape was a disadvantage.

Mazzard F12/1 was the most useful indicator. Symptoms were usually clear with good differentiation between diffuse mottles, ring and rusty mottles, and the control plants were nearly always evenly coloured and free from necrotic spots. F12/1 proved, however, to be a poor indicator of rasp leaf.

Indexing in the glasshouse.

The experiments in the glasshouse had two main objectives—firstly to investigate the host range of the viruses and their symptoms in the glasshouse compared with those obtained by outdoor working, and secondly to find the best method of utilizing the glasshouse space for virus experiments.

Glasshouse technique.

The three contrasted methods of using the glasshouse were :

1. Seedlings in pots were inoculated with chip-buds in August, 1950, and brought into the glasshouse in March, 1951, when they were cut back to two nodes above the inoculating bud.

2. Seedlings of the same age and treated in the same way as those used in 1 were inoculated in March, 1951.

3. Seedlings germinated in the spring of 1951 were inoculated in May and June, 1951, and cut back as in 1.

Thirty-six peach and 36 apricot seedlings were used in treatment 1 ; 24 peach, 10 apricot and 21 morello in treatment 2 ; 60 peach, 40 apricot and 38 morello seedlings (in addition to a larger number used in other host range experiments) received treatment 3.

The yearling plants resulting from treatments 1 and 2 proved to be too large for glasshouse work, took longer to develop symptoms and were more liable to suffer from pot-binding and deficiency mottles than the young seedlings used in treatment 3.

In 1952, only young seedlings (under 6 months old) were used, both for host range studies and for large scale indexing in the search for healthy material of commercial varieties. The method was satisfactory when the seedlings were inoculated in May or June, but many of those inoculated later failed to grow sufficiently after being cut back.

Host range investigations.

In the search for suitable indicator plants, clonal mazzard and seedlings of apricot, peach, myrobalan, mahaleb, morello and mazzard cherries were inoculated with viruses causing the six symptom groups already described. One hundred and fifty-four different sources of virus were used, so that " contaminating " viruses and strain variation could be studied. The results obtained from both glasshouse and nursery experiments have been summarized in Table II, in which only the main symptoms on each host have been included, and complex symptoms resulting from multiple infection have been analysed where possible.

Latent viruses.

In these investigations, several latent viruses were transmitted and the test plants developed symptoms which were not seen in orchards.

Necrotic ring spot. The mazzard clone, F12/1, proved to be very sensitive to necrotic ring spot (Moore and Keitt, 1944) and several strains were distinguished by the different size and frequency of the necrotic spots (Fig. 10), and by the degree of necrosis, which may be either surface etching or complete necrosis of the ring, or necrosis of the whole area inside the ring.

Dusty yellows. The term " dusty yellows " is descriptive of a symptom seen only on F12/1 following inoculation from several symptomless sweet and sour cherry trees ; the leaf appears as if it had been dusted with fine pale yellow powder and then tapped so that irregular patterns (Fig. 11) are formed.

Sunken mottle. Inoculations from several different sources transmitted a virus which caused a dark green vein banding or mottle on peach ; the dark green areas

TABLE II.

Summary of main symptoms on Prunus *spp. inoculated with virus from 154 sources.*

Symptom group	Phase*	MAZZARD F12/1	PEACH	MORELLO	APRICOT	MAHALEB	MYROBALAN
TATTER LEAF Spring leaves necrotic	Acute	Severe leaf necrosis	Severe necrosis	Severe leaf necrosis and dieback	Mottle; line pattern; dieback	Ring patterns; stunting	Few faint rings
	Chronic	Few necrotic spots	Stunting; ring and line pattern	Stunting			Ring mottle
TATTER LEAF Summer leaves necrotic	Acute	Red and necrotic line pattern on summer growth	Ring pattern	Mottle	Necrotic spots	Yellow rings	—
	Chronic		Chlorotic V-pattern; stunting	Necrotic line pattern; stunting	Ring mottle ; stunting	Necrotic line pattern ; stunting	—
RASP LEAF	Acute	None	?None	Leaf distortion, enations, stunting	Green veinlet net	Surface etch	Veinlet clearing; stunting
	Chronic	Coarse narrow leaves ; stunting ; few enations	Stunting		Stunting	None	Stunting
ROSETTE	Acute	Leaf ruffling, vein clearing, mottle ; rosetting of spring growth	Tip dieback	Necrotic spots and rosetting	None	None	Leaf distortion and rosetting
	Chronic		None	Stunting			
RING MOTTLE	Acute and Chronic	Ring and "oak leaf" patterns	None	None	Faint ring mottle	Ring patterns	None
RUSTY MOTTLE	Acute	Yellow veinlets	?Few rusty spots	None	None	None	None
	Chronic	Yellow and red mottle	Slight stunting	Slight stunting	Rusty rings		
DUSTY YELLOWS	Acute	Faint mottle	?Yellow mottle	?Slight yellowing	None	None	—
	Chronic	Dusty yellow patterns	None	—			
SUNKEN MOTTLE	Acute and Chronic	?Necrotic spots on late growth	Dark green vein banding sunken on upper leaf surface	None	None	None	None
NECROTIC ETCH	Acute	Necrotic spots (late)	Vague rings; ?sunken mottle	—	—	—	—
	Chronic	Etched rings					

* *Acute* : symptoms during first growing season after inoculation ; *Chronic* : symptoms during second season.

were depressed on the upper surface of the leaf, and looked shiny in contrast to the normally matt surface (Fig. 12). This virus has not caused leaf symptoms on sweet, sour or mahaleb cherries.

Canker virus. Observations and experiments still in progress suggest that a certain type of stem canker in cherry may be caused by a virus and not by the usual canker-forming organism, *Pseudomonas mors-prunorum* Wormald. Evidence regarding canker caused by virus on cherry is inconclusive, but a virus transmitted from cherry caused severe stem cankering on apricot seedlings which were inoculated in August and which developed bark necrosis and gum pockets in the following summer.

VIRUS-FREE CLONES.

A need for virus-free clones of the more important commercial varieties became apparent early in the course of this work. They were required for the determination of their symptom expression with different viruses in the selection of indicator varieties and as an aid in field surveys ; and also for the initiation of experiments to determine the effects of different viruses on vigour and cropping.

Preliminary tests on the clones propagated at East Malling showed that few of the scion varieties were virus-free, although most of the rootstock clones were not infected. Of thirty-six varieties indexed, only two were apparently virus-free, and these were the comparatively new varieties, Merton Heart and Merton Bigarreau.

A programme of selection was begun in 1951, with the aim of testing each year ten apparently healthy orchard trees of each of two varieties. A search was made for symptomless trees of the varieties Early Rivers and Roundel in the first year, and of Gaucher and Kent Bigarreau in 1952. Sufficient budwood was collected from each selected tree for indexing on peach and mazzard F12/1 and for the propagation of ten trees on F12/1 rootstocks. Symptomless trees of Early Rivers and of Kent Bigarreau were found without difficulty, but only five of Roundel and eight of Gaucher have been seen so far without symptoms of rusty mottle ; each of these Roundel trees proved on testing to be infected with rusty mottle virus (tests on Gaucher and Kent Bigarreau are incomplete). Of the nine tested trees of Early Rivers only two were apparently free from ring spot, and one of these two may not be virus-free.

Latent virus infection caused bud-failure in propagation and reduced growth during the first year. The virus-free clone of Early Rivers yielded ten trees out of ten budded, whereas five clones infected with necrotic ring spot yielded two to eight trees out of ten, with a mean of 5·2. The five infected clones of Roundel averaged 5·6 trees out of ten budded. Differences in growth were equally marked : at the end of the first season's growth, trees of the virus-free Early Rivers clone averaged 2·7 lb. per tree compared with 1·7 lb. per tree for the infected Early Rivers clones.

These early results indicate that virus-free clones would increase nursery efficiency and produce young trees more vigorous than those from clones infected even with " mild " viruses.

DISCUSSION.

The results of this investigation show that the mazzard clone F12/1, which is available in adequate quantity from established layer beds, can form the first

" screen " in testing material for freedom from viruses. Peach and apricot seedlings, for which large quantities of seed must be obtained from overseas, can then be used for latent virus testing of material which has caused no symptoms on F12/1. In this way it should be possible to test a large number of scion-sources with the minimum number of indicator plants, an economy of space which is of great importance in view of the large volume of indexing involved in the search for virus-free mother trees of the many varieties of cherries now grown commercially. For final tests, it may be desirable to use the ornamental cherries, Kanzan and Shirofugen when virus-free clones have been propagated, because they are even more sensitive than peach to some virus strains (Milbrath and Zeller, 1945).

Much analytical work is needed to separate the component viruses in the symptom groups, and there are two outstanding gaps in our knowledge to be filled before these virus diseases can be viewed in perspective in relation to other aspects of cherry growing. The first is our lack of information on the degree of damage they cause. It is evident from visual observations alone that certain viruses, those in the tatter leaf and rasp leaf groups especially, cause considerable loss of crop, but they are rare compared with those in the mottle group, the effect of which is difficult to judge by eye. But if the mottle viruses should reduce yield by a mere 5%, the aggregate loss to the cherry industry would be far greater than the aggregate from tatter leaf and rasp leaf. The effect of three viruses independently in stunting clonal F12/1 suggests that one important virus effect may be to delay the cropping of young trees. Trials have been started to compare virus-infected with virus-free trees of Napoleon, Merton Heart, Merton Bigarreau and Early Rivers.

To find the effects of the less prevalent viruses under commercial conditions it is not necessary to have completely virus-free trees. In fact, it might be argued that the use of virus-free trees would be misleading because most commercial trees are infected with one of the mottle viruses. The reduction in yield from tatter leaf infection, for example, could be estimated by inoculating bearing trees (in a statistical design) in a mature orchard now free from tatter leaf. It is difficult, if not impossible, to give rational advice on the treatment of affected orchards, whether or not to destroy infected trees and replant, without data on crop losses to be expected from virus infection.

The second gap in our knowledge is that relating to insect vectors. Our mapped orchards have already indicated that some tree-to-tree spread of tatter leaf occurs, but records over a longer period and in a greater number of orchards are required before we can definitely assume the presence of a vector. Some spread may have occurred by root-grafting ; or the apparent increase in the number of infected trees may be due to a recurrence of symptoms of the acute stage on trees which have been in the chronic stage for years. Much information on this aspect could be obtained from field experiments designed primarily to estimate crop reduction. There is, however, no reason why trials with insects likely to be vectors should await incontrovertible proof that spread by insects occurs. The vectors known to transmit peach and cherry viruses in America are all leafhoppers, and attention should be concentrated on this group at first.

A common practice which should be discouraged at once is that of including sour and sweet cherries in the same orchard. Although sour cherries suffer severe shock effects when first infected, they may recover and grow vigorously with no clear symptoms. Symptoms of sour cherry yellows, which are transient and easily

attributed, by the uninitiated, to a June drought were seen on some Kentish Red trees scattered in sweet cherry orchards and on at least two of the Malling clones. According to many workers in North America (e.g. Keitt and Clayton, 1943; Berkeley and Willison, 1948) necrotic ring spot virus is invariably a component of yellows, and some strains of necrotic ring spot cause symptoms of the tatter leaf type on sweet cherry. A Kentish Red tree in the orchard surveyed at East Sutton proved to be a symptomless carrier of a tatter leaf virus, and it seems probable that the tatter leaf in Early Rivers there is caused partly by the necrotic ring spot virus which has spread from the scattered Kentish Red trees.

The identification of the virus diseases of cherries in England with those of North America is complicated by environmental differences and virus strain variation which has already led to confusion between workers in different regions of North America. Another difficulty at present, though obviously surmountable, is that different varieties are grown in the different countries, and even when the same names are used, it is by no means certain they are applied to the same variety (Grubb, 1949). A start has been made, however, by the introduction of virus-free scion wood of the varieties Bing, Napoleon and Montmorency used for indexing in Canada. By using the same indicator clones, we should be able to compare virus diseases in England and in Canada in greater detail than is possible at present.

The handbook on " Virus Diseases and Other Disorders with Virus-like Symptoms of Stone Fruits in North America ", published by the U.S.A. Department of Agriculture (1951), describes the symptoms of most known viruses on different *Prunus* spp. Considering our symptom groups in relation to American descriptions, the following tentative conclusions are reached.

Rosette.

This disease agrees most closely with that called " mottle leaf " in the Western States of America and Canada, but there are differences which suggest either that rosette is caused by a different virus or that our source is contaminated with another virus. Although symptoms of rosette on Schrecken resemble those in photographs of severe mottle leaf on Bing and Napoleon in the handbook, it is stated there that sour cherry is " practically symptomless " with mottle leaf (Reeves, 1941), whereas in this investigation rosette caused pronounced symptoms of stunting and necrotic spotting in sour cherry seedlings, while mazzard and peach indicated the absence of necrotic ring spot. The diseases appear very similar in some other respects such as the shortening of the internodes to form rosettes and the masking of symptoms during summer growth.

Rasp leaf.

The enations caused by the rasp leaf virus are so characteristic and descriptions of them in North America (Bodine and Newton, 1942) agree so well with those observed in England that there seems little doubt that the same virus is the cause. It seems less certain that the " Pfeffinger " disease reported by Blumer (1950) and the " Eckelrader " diseases of Mulder (1951) are identical with rasp leaf; the " olflecken ", which are characteristic of the former diseases and which have not been observed here or mentioned by North American workers, may be caused by a virus component additional to the rasp leaf virus causing the enations.

Tatter leaf.

There is little doubt that more than one virus is causing severe necrosis of the tatter leaf type in English orchards. In the literature from North America, three viruses are described which cause similar symptoms :

(i) Necrotic ring spot of sour cherry, which causes chlorotic rings, necrosis and tattering as a shock symptom on sweet cherry (Moore and Keitt, 1944). The disease in the East Sutton orchard, where Early Rivers trees have shown pronounced symptoms in one year, followed by partial recovery in subsequent years, probably has a strain of necrotic ring spot as one component.

(ii) Tatter leaf of sweet cherry (Willison and Berkeley, 1946) which causes symptoms similar to those of necrotic ring spot on sweet cherry but can be distinguished on sour cherry. Although acute and chronic stages occur also with this disease, Willison (*in litt.*) states that tatter symptoms do recur in successive years on some hosts. The recurrent type of tatter leaf on Early Rivers in the Yalding orchard may be due to a strain of the virus causing tatter leaf in Ontario.

(iii) Necrotic rusty mottle (Richards and Reeves, 1951) causes severe leaf necrosis, but the associated symptom of severe dieback, even of the older branches, has not been observed in England without the complicating factor of bacterial canker.

Mottles.

The ring or vein-banding mottle so commonly found on cherry leaves in England may be attributed to the ring spot virus (Cochran, 1946), although inoculated peach and sour cherry did not develop symptoms in our experiments. Mild necrotic spotting has frequently been associated with the mottle on mazzard F12/1 infected by grafting and it is possible that a mild strain of the necrotic ring spot or of the tatter leaf virus is involved. Cross-protection experiments are in progress to test this possibility.

Rusty mottle which was sometimes a " contaminant " in transmission tests seems to resemble in most respects the mild rusty mottle in Oregon (Zeller and Milbrath, 1947).

Sour cherry yellows.

The symptoms of leaf yellows, June leaf-fall and reduced spur systems described by Berkeley and Willison (1948), have been observed on sour cherry trees in Kent but, as they were not seen until 1951, transmission experiments have not yet established complete identity with the disease in North America, although the reactions of peach and apricot agree with those described for yellows.

[*Note added in proof:* Transmission to Montmorency has since confirmed the presence of the sour cherry yellows complex.]

In the absence of any statistical evidence regarding the effect of these viruses on yield in England, it is relevant to note that the economic importance of each of them is reported to be considerable in regions of North America where they are prevalent. Necrotic ring spot of sour cherry is a possible exception to this statement, its effect alone on the cropping of sour cherry being slight ; as a component of the sour cherry yellows complex, however, it contributes to " the most important known virus disease of sour cherry " (Keitt *et al.*, 1951).

PLATE I

Fig. 1.

Crinkle and mottle symptoms of rosette on Schrecken sweet cherry.

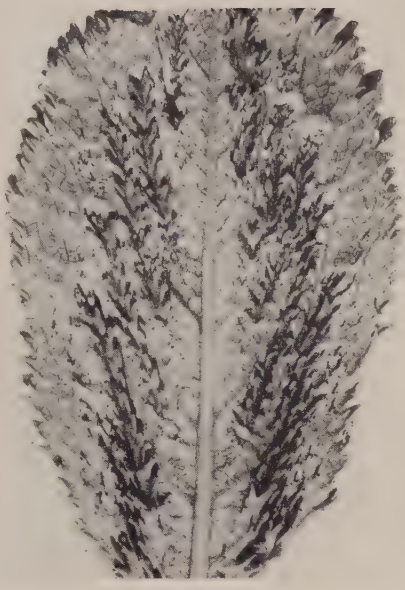

Fig. 2.

Enations on leaf of Frogmore sweet cherry infected with rasp leaf.

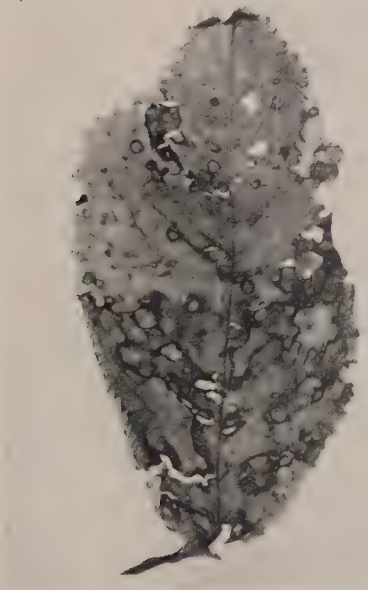

Fig. 3.

Necrotic areas on leaf of Early Rivers sweet cherry infected with tatter leaf.

Fig. 4.

Necrosis in a line pattern, typical symptom associated with tatter leaf on summer growth.

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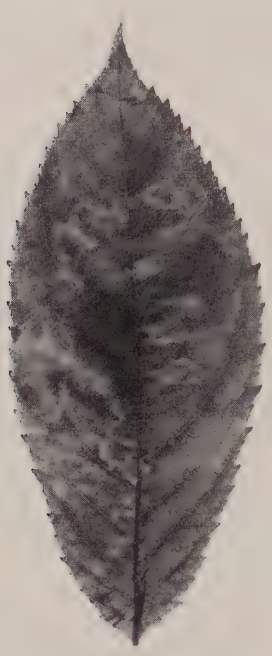

FIG. 5.
Ring mottle on Early Rivers sweet cherry.

FIG. 6.
Chlorotic mottle of "oak leaf" type on mazzard F12/1.

FIG. 7.
Vein clearing in bands on Early Rivers sweet cherry.

FIG. 8.
Yellow veinlets, an early season symptom of rusty mottle on mazzard F12/1.

FIG. 9.
Enations on leaf of Morello sour cherry seedling infected with rasp leaf.

FIG. 10.
Etched rings caused by a strain of necrotic ring spot virus in mazzard F12/1.

FIG. 11.
"Dusty yellows" symptoms on mazzard F12/1.

FIG. 12.
Symptom on peach of a virus latent in cherry. This leaf has been photographed by reflected light so that shiny areas, actually dark green, appear white.

SUMMARY.

Virus diseases found in cherry trees in England are described in six groups: rosette, rasp leaf, tatter leaf, chlorotic mottles, rusty mottle and yellows. All these diseases, except rasp leaf, are prevalent, and the aggregate loss of crop may be considerable, but there are no yield records from which it can be estimated.

Most orchard trees are infected with one or more viruses, and selection and testing is proceeding to obtain virus-free material of important varieties.

Transmission to different *Prunus* species has shown which hosts are useful test plants for the particular viruses concerned, the mazzard clone F12/1 being the most valuable as a general indicator.

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REFERENCES.

Berkeley, G. H., and *Willison, R. S.* (1948). Yellows and necrotic ring spot of sour cherries in Ontario. Phytopathology, **38**, 509.

Blumer, S. (1950). Viruskrankheiten an Kirschbäumen im Gebiete des Zurichsees. Schweiz. Zeit. Obst- und Weinbau, **59**, 286.

——— and *Meyer, A.* (1947). Das Kirschbaumsterben im Baselland. Schweiz. Zeit. Obst- und Weinbau, **56**, 203.

Bodine, E. W., and *Newton, G. H.* (1942). The rasp leaf of cherry. Phytopathology, **32**, 333.

Cochran, L. C., and *Hutchins, L. M.* (1941). A severe ring-spot virosis on peach. Phytopathology, **31**, 860.

Garner, R. J. (1946). Grafters' Handbook. Faber & Faber, London.

Grubb, N. H. (1949). Cherries. Crosby Lockwood & Son, Ltd., London.

Hildebrand, E. M. (1942). Indexing cherry yellows on peach. Phytopathology, **32**, 712.

Keitt, G. W., and *Clayton, C. N.* (1943). A destructive virus disease of sour cherry. Phytopathology, **33**, 449.

——— *Berkeley, G. H., Cation, D., Clayton, C. N., Hildebrand, E. M., Moore, J. D.*, and *Rasmussen, E. J.* (1951). [*In*] Virus diseases and other disorders with viruslike symptoms of stone fruits in North America. U.S.D.A. Handb., **10**, 152.

Kotte, W. (1951). Die Schmalblättrigkeit der Süsskirsche (Pfeffingerkrankheit) auch in Deutschland. Phytopath. Ztschr., **17**, 468.

Milbrath, J. A., and *Zeller, S. M.* (1945). Latent viruses in stone fruits. Science, **101**, 114.

Moore, J. D., and *Keitt, G. W.* (1944). Host range studies of necrotic ring spot and yellows of sour cherry. Phytopathology, **34**, 1009.

Mulder, D. (1951). De Eckelrader virusziekte van zoete kersen. Mededelingen Directeur van de Tuinbouw, **14**, 217.

Reeves, E. L. (1941). Mottle leaf, a virus disease of cherries. Jour. agric. Res., **62**, 555.

Richards, B. L., and *Reeves, E. L.* (1951). Necrotic rusty mottle. [*In*] Virus diseases and other disorders with viruslike symptoms of stone fruits in North America. U.S. Dept. of Agric. Handb., **10**, 120.

Stoll, K. (1951). Über die Symptome der Pfeffingerkrankheit der Kirschbäume. Phytopath. Ztschr., **18**, 293.

——— (1952). Das Kirschbaumsterben im Baselland. Landw. Jb. Schweiz., **66**, 255.

Willison, R. S. (1950). Virus diseases of fruit trees. 1. Some field observations on stone fruit in Southern England. Ann. Rep. Long Ashton Res. Sta. for 1949, 64.

——— and *Berkeley, G. H.* (1946). Tatter leaf of sweet cherry. Phytopathology, **36**, 73.

Zeller, S. M. and *Milbrath, J. A.* (1947). Mild rusty mottle of sweet cherry. Phytopathology, **37**, 77.

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CHEMICAL COMPOSITION OF CORTLAND APPLE LEAVES IN RELATION TO NUTRITIONAL TREATMENT*

By C. A. EAVES and A. KELSALL
Dominion Experimental Farm, Kentville, Nova Scotia

THE chemical investigations to be reported here are part of an experiment primarily designed to assess the influence of fertilizer treatments on the quality of Cortland apples at harvest and in storage. A preliminary report on this latter aspect has been published (8) and also observations in respect to yields and growth (12).

Similar experiments in the past have frequently given results which were inconclusive because they were related to treatment only, with little attention to the physiological capacity of the tree to absorb the nutrients under study. It was felt, therefore, that the analysis of leaf tissue should help to fill this gap and clarify some of the many chemical interactions present in this comprehensive experimental layout.

During the past five years the use of dolomitic limestone in Nova Scotian orchards has become general for the improvement of cover crops, but its direct influence on apple trees is largely unknown. Investigations at this Station prior to 1940 showed that heavy lime applications resulted in corky core of McIntosh apples, a disease associated with boron deficiency. Recently, the incidence of magnesium deficiency in apple and cherry trees, highbush blueberries and potatoes, has been established in this area. It is known, furthermore, that local soils are well supplied with potash, which may be adversely affected by additions of dolomitic limestone, a material which, as will be shown later, prevents the occurrence of magnesium deficiency. In a recent report, Hill *et al.* (10) have shown that a lack of potash results in poor quality fruit, particularly when the N/K ratio is high, but that applied phosphorus has no observable influence.

Boynton and his co-workers (2, 3, 4, 5) have added considerably to the present knowledge of the nutrient status of McIntosh apple trees, and the data reported herein will be discussed in the light of their results. This present investigation is chiefly concerned with nutritional relationships in Cortland apple leaves and the records of growth and yield are summarized for reference in Appendix 1.

MATERIALS AND METHODS

The orchard used is situated in the Annapolis Valley of Nova Scotia on a level and fairly uniform area of Nictaux sandy loam (9), low in fertility and with pH 5·0. The orchard consists entirely of twenty-one-year-old Cortland trees planted twenty feet apart each way, in sod strip and cultivated between each row. There are sixteen rows with thirty trees in each. For experimental purposes the orchard is divided into four blocks receiving different basic treatments each containing three rows and separated by guard trees. Fifteen annual treatments

* Contribution No. 788 from the Division of Horticulture, Experimental Farms Service, Nova Scotia.

applied to alternate trees in the rows are superimposed across the blocks giving a total of sixty plots, each containing three trees.

Table I, which also records the dry weight percentage of magnesium in the leaves, gives an outline of the experiment and of the treatments used.

TABLE I.

Magnesium levels (dry weight percentage) and deficiency symptoms,† Cortland apple leaves, 1st October, 1951.

Plot No.	Treatment* 1,000 lb. per acre:	Block treatments applied 1945 and 1950			
		A Untreated	B 1 ton Lime	C 1 ton Lime plus 1,000 lb. Superphosphate	D 1,000 lb. Superphosphate
	N P K				
1	0–0–0	0·145	0·186	0·200	0·176
2	0–10–0	0·118 S	0·185	0·162	0·125 S
3	0–0–5	0·131 VS	0·212	0·156	0·132 S
4	3–0–0	0·162	0·226	0·175	0·141
5	9–0–0	0·165	0·189	0·186	0·154
6	16–0–0	0·142	0·178	0·180	0·152
7	0–10–5	0·140 S	0·153	0·144	0·156 S
8	0–5–10	0·120 S	0·140	0·146	0·095 S
9	3–10–5	0·118 S	0·149	0·139	0·117 S
10	3–5–10	0·123 S	0·184	0·157	0·148 VS
11	3–1⅔–1⅓	0·110 Sl	0·200	0·166	0·142 M
12	9–10–5	0·140 Sl	0·178	0·125	0·130 M
13	9–5–10	0·129 Sl	0·166	0·180	0·152 M
14	16–10–5	0·146 Sl	0·172	0·164	0·157 M
15	16–5–10	0·140 Sl	0·178	0·171	0·132 M
	Average	0·137	0·158	0·163	0·140

* N=Ammonium Nitrate, 33%
P=Superphosphate, 20%
K=Muriate of Potash, 60%

† Deficiency Symptoms VS=Very severe S=Severe Sl=Slight M=Medium

The plots of the experiment are not randomized, but this is somewhat offset by the uniformity of the orchard and the nature of the treatments which, in certain instances, allows them to be grouped.

The winter rainfall prior to sampling was much the same for the two years; but the comparative figures for April and May of each year were, respectively, 1950, 2·52 in., 0·94 in., and 1951, 3·71 in., 3·27 in. During the three years 1949-51, sprinkler irrigation was used from June onwards, care being taken to insure that all plots received the same quantity of water from this source.

Leaves were sampled from the middle of the current season's growth, 33 from each of three trees, during the second week in July, 1950 and 1951. These were dried immediately in a tunnel drier at 160° F. for four hours and then finely ground in a Wiley mill.

Analytical procedures described by Lindner (13) were used in 1949, but recoveries were not satisfactory, and later those used by Hill *et al.* (10) were adopted. Duplicate samples of ground tissue were used for both total nitrogen determinations and ashing.

Results.

Figures 1 and 2 show a series of histograms depicting the chemical composition of all samples for 1950 and 1951. The plot values are placed in three main groups, namely, (1) receiving no nitrogen, (2) nitrogen only, (3) nitrogen plus minerals. The shaded areas represent values above the general average. The results will be discussed under 1. Block treatments, 2. Annual treatments, and 3. Chemical composition of leaves at two dates of sampling.

Block treatments.

Table II summarizes the averages of the nutrient content of leaves from each block for 1950 and 1951.

Table II.

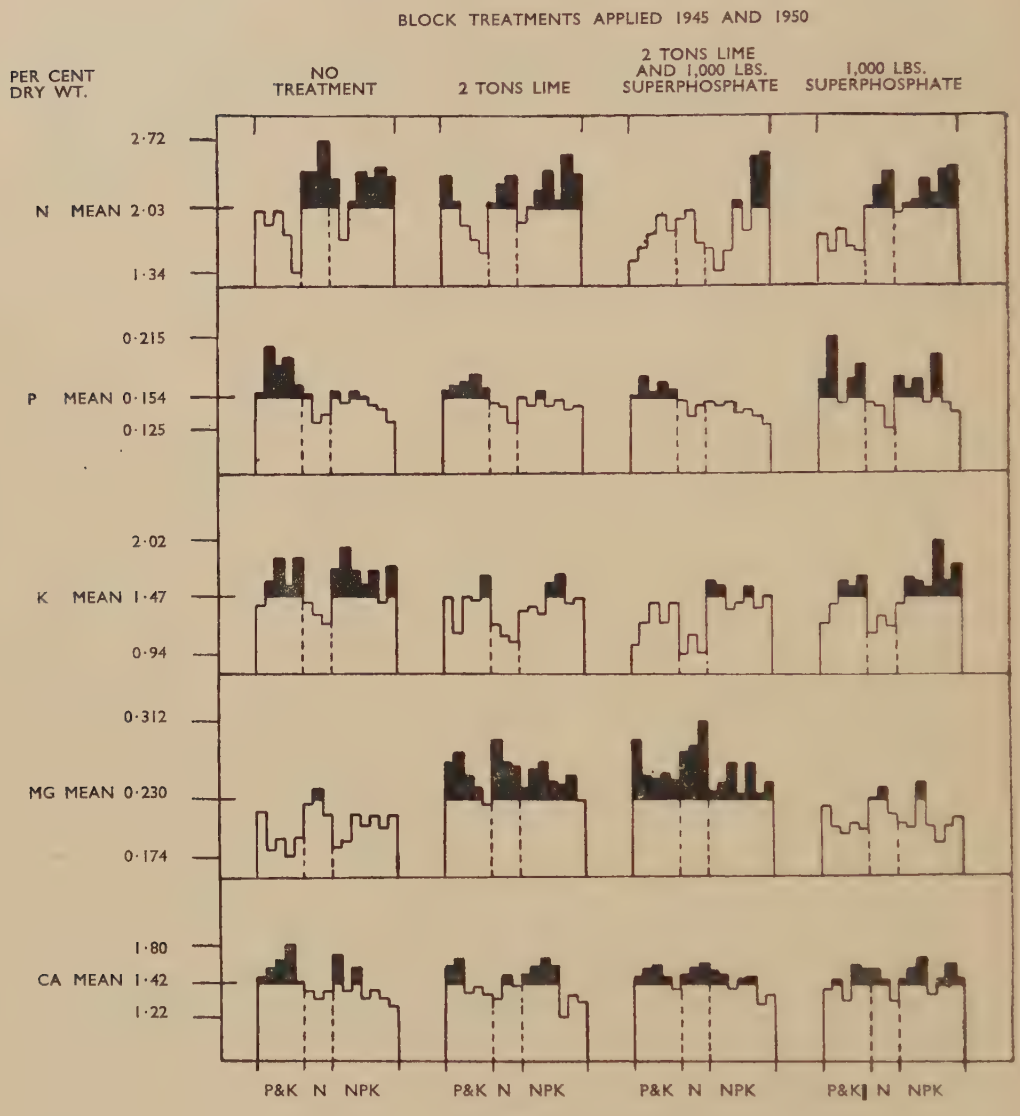
Chemical composition of Cortland apple leaves as influenced by lime and superphosphate applications.

Year	Treatment	Percentage of dry matter				
		N	P	K	Mg	Ca
1950	Nil	2·146	0·157	1·81	0·204	1·40
	2 tons lime	2·106	0·151	1·34	0·267	1·38
	2 tons lime, 1,000 lb. superphosphate	1·86	0·147	1·25	0·263	1·43
	1,000 lb. superphosphate	2·01	0·161	1·48	0·213	1·44
	Average	*2·03*	*0·154*	*1·47*	*0·230*	*1·416*
1951	Nil	2·05	0·195	1·98	0·137	1·63
	2 tons lime	1·88	0·185	1·71	0·158	1·37
	2 tons lime, 1,000 lb. superphosphate	1·89	0·178	1·72	0·163	1·21
	1,000 lb. superphosphate	1·84	0·187	1·79	0·140	1·31
	Average	*1·91*	*0·187*	*1·79*	*0·149*	*1·38*
	Percentage difference based on 1950	−6·4	+20·7	+21·8	−34·8	−2·8

From observations of the density of foliage and depth of colour, the blocks receiving dolomitic limestone have consistently looked better than the others. These observations were not borne out by the nitrogen content, which was lower in the limed blocks in both years. The reduction in 1951 (Table II), is believed to be due to the higher rainfall in that year.

The inverse relationship between nitrogen and phosphorus is clearly shown in the histograms and this is further indicated by the figures for 1951 as compared with 1950, which show a 20·7% increase in phosphorus content as against a decrease in nitrogen of 6·4%. The addition neither of lime nor of superphosphate resulted in an increase in the uptake of phosphorus.

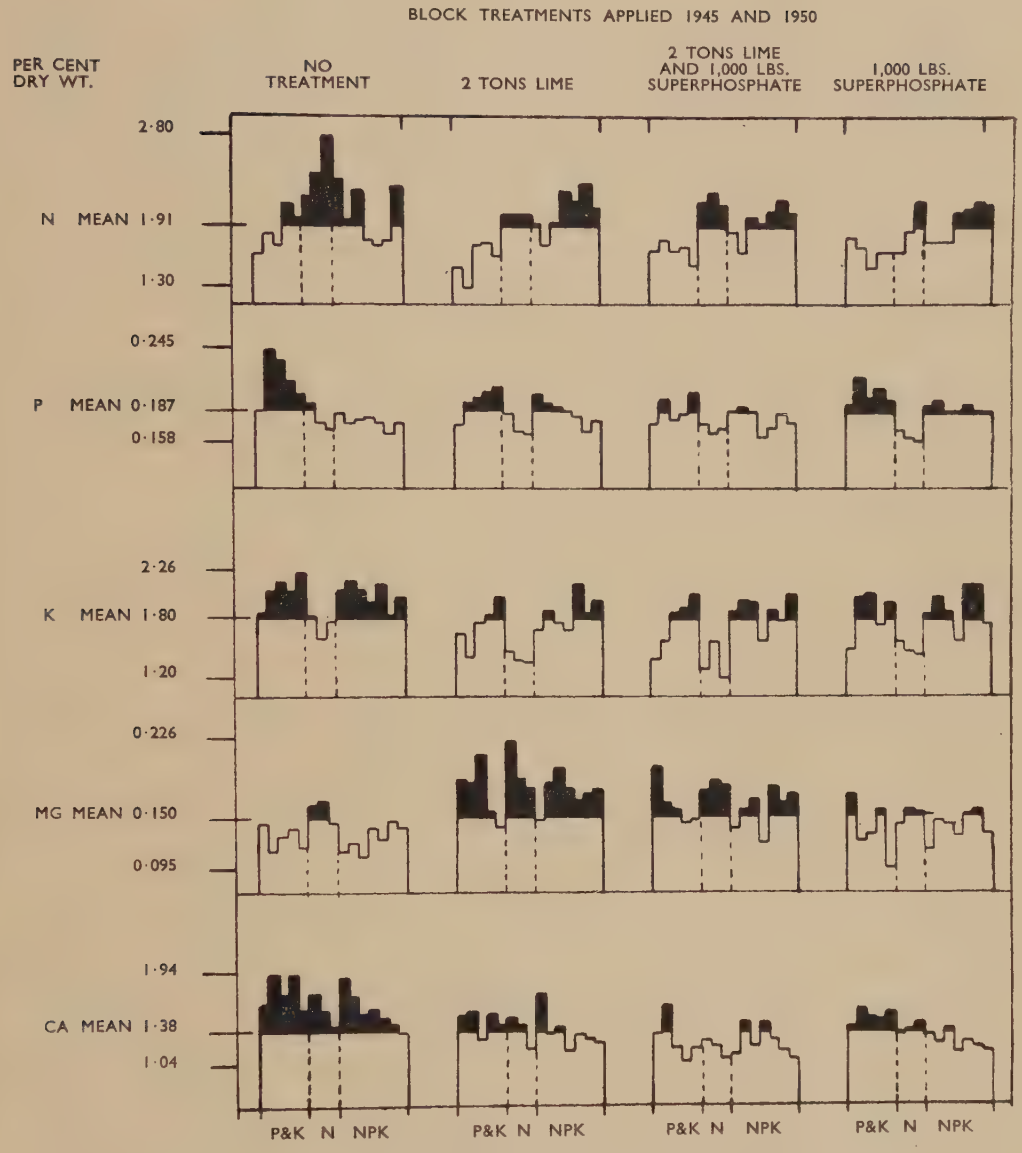
The uptake of potassium was reduced in the trees receiving lime, particularly in 1950, and it is evident from both histograms that potassium is antagonistic to the magnesium in the dolomitic limestone. In 1950 several leaf samples from the limed series contained less than 1% potassium, and it was observed that the foliage on the trees, particularly the oldest leaves on the terminal growth, developed a reddish



ANNUAL TREATMENT IN EACH BLOCK (1,000 LBS/A)

PLOT NUMBERS	1	2	3	7	8	4	5	6	9	10	11	12	13	14	15
N	0	0	0	0	0	3	9	16	3	3	3	9	9	16	16
P	0	10	0	10	5	0	0	0	10	5	1·6	10	5	10	5
K	0	0	5	5	10	0	0	0	5	10	1·3	5	10	5	10

FIG. 1.
Nutrient levels in Cortland apple leaves, 1950.



ANNUAL TREATMENT IN EACH BLOCK (1,000 LBS/A)

	PLOT NUMBERS														
	1	2	3	7	8	4	5	6	9	10	11	12	13	14	15
N	0	0	0	0	0	3	9	16	3	3	3	9	9	16	16
P	0	10	0	10	5	0	0	0	10	5	1·6	10	5	10	5
K	0	0	5	5	10	0	0	0	5	10	1·3	5	10	5	10

Fig. 2.
Nutrient levels in Cortland apple leaves, 1951.

bronze hue late in August. There was no sign of this in the following year when the average potassium content increased by 21·8%.

During the period 1948-51 magnesium deficiency has increased in the unlimed trees and, in 1951, some trees became partially defoliated in August, when there was a general decrease of 34·8% in magnesium content. It is thought that as the trees were irrigated at this time, considerable leaching of magnesium in the soil must have taken place. The first symptoms were seen at the beginning of August on the superphosphate block only but, by the end of September, the trees on the untreated block were also affected (Table I).

Table I clearly shows that dolomitic limestone greatly increases the magnesium content of the leaves with the resultant lack of deficiency symptoms. As also observed by other workers (1), (2), the symptoms are apparently reduced where nitrogen has been applied to the trees.

The calcium content of the leaves in both years (Figs. 1, 2) was unaffected by the addition of lime and there was very little difference between the years, except on the untreated block.

Annual treatments.

The applications of nitrogen, potassium and phosphorus are reflected in the chemical composition of the leaves as shown in Table III and Fig. 3.

TABLE III.

Influence of annual applications of nitrogen, superphosphate and potash on the chemical content of Cortland apple leaves.

Treatment	1950 (Dry year)					1951 (Wet year)				
	N	P	K	Mg	Ca	N	P	K	Mg	Ca
Control	1·90	0·160	1·22	0·251	1·45	1·64	0·180	1·58	0·175	1·44
P only	1·76	0·191	1·29	0·229	1·53	1·65	0·214	1·76	0·147	1·66
K only	1·85	0·164	1·58	0·225	1·41	1·65	0·203	1·96	0·133	1·40
P + K	1·76	0·175	1·49	0·224	1·47	1·70	0·206	1·91	0·145	1·49
3N (all plots) ..	1·94	0·154	1·41	0·232	1·42	1·93	0·185	1·82	0·153	1·42
9N (all plots) ..	2·20	0·146	1·45	0·263	1·36	2·04	0·173	1·75	0·158	1·31
16N (all plots) ..	2·39	0·134	1·35	0·235	1·32	2·17	0·172	1·75	0·159	1·23
N only	2·20	0·138	1·09	0·257	1·38	2·13	0·170	1·48	0·170	1·36

The increases in nitrogen levels are closely associated with growth and yields. Nevertheless, the factors affecting fruit quality are not so clear, nor are those causing the variations in magnesium deficiency. The definite interactions shown in Figs. 1 and 2 make it clear that the nutrient levels were closely linked and each constituent could be studied only in relation to the others. Accordingly, scatter diagrams were made showing for example, the relationships between nitrogen and phosphorus levels within each block, and for the entire sixty plots. It was seen that definite correlations existed and coefficients were calculated. These are shown in Table IV.

It will be seen from the foregoing Table that N–P and K–Mg correlations are strongly negative, in spite of the wide variety of nutritional conditions. This leads

to the conclusion that these are expressions of ion antagonism. The P–Mg relationship is likewise negative and the levels of Mg are depressed in the plot receiving annual treatments of superphosphate only. (See Fig. 3.) The correlation between P and Mg for the limed blocks approached zero in both years and this is probably due to the increased levels of applied and leaf magnesium as opposed to the relatively lower

Table IV.

Interrelationships between chemical constituents in Cortland apple leaves expressed as correlation coefficients.

Inter-relationship	Year	Untreated	Lime	Lime plus super-phosphate	Super-phosphate	Totals
N–P	1950	−·598	−·709	−·722	−·822	−·532
	1951	−·337	−·501	−·628	−·447	−·371
N–K	1950	−·620	−·281	+·085	+·113	−·038
	1951	−·036	−·011	+·035	+·014	±0
N–Mg ..	1950	+·582	+·334	−·147	+·172	−·024
	1951	+·178	+·065	+·374	+·332	+·522
N–Ca	1950	−·434	+·152	−·483	−·081	−·217
	1951	−·179	−·582	−·234	−·664	−·750
P–K	1950	+·343	+·317	−·207	+·247	+·285
	1951	+·300	±0	+·297	+·515	+·067
P–Mg	1950	−·709	−·105	±0	−·479	−·410
	1951	−·654	−·164	−·186	−·214	−·564
P–Ca	1950	+·771	+·118	+·388	+·206	+·401
	1951	+·506	+·222	+·112	+·273	+·017
K–Mg	1950	−·555	−·698	−·712	−·549	−·700
	1951	−·839	−·446	−·427	−·285	−·542
K–Ca	1950	+·260	−·396	−·310	+·262	−·014
	1951	+·236	−·245	−·638	+·072	+·261
Mg–Ca ..	1950	−·658	+·381	+·430	±0	±0
	1951	−·238	−·134	−·048	−·186	−·355

Significant correlation coefficients (in black type).
Blocks ±·514 Totals ±·255

levels of phosphorus. The decrease of phosphorus in the leaves from the trees which received lime and annual applications of superphosphate was approximately 20% each year. Again, Table II shows that the average phosphorus content of leaves from the block receiving lime and superphosphate is consistently low in relation to the remaining blocks.

The most consistently positive correlations are P–K and P–Ca. The same is true of K–Ca, except for the limed blocks where correlations are negative; although only one of these correlation coefficients is significant, if true, the reversal may be due to the great decrease in potassium content, since calcium remains at much the same level.

The N–K, N–Ca, and N–Mg correlation coefficients are difficult to interpret because of the pronounced influence of applied nitrogen. Boynton and Compton (2) have shown that the N–K negative relationship may be due to the increase in volume of leaf tissue resulting from applied nitrogen, thereby diluting the concentration of potassium.

In these data there is no correlation between nitrogen and potassium on the whole, but there is a definite decrease in potassium when nitrogen only is applied, particularly in the limed blocks. On the other hand, when a complete fertilizer is used the potash level is normal (Fig. 3).

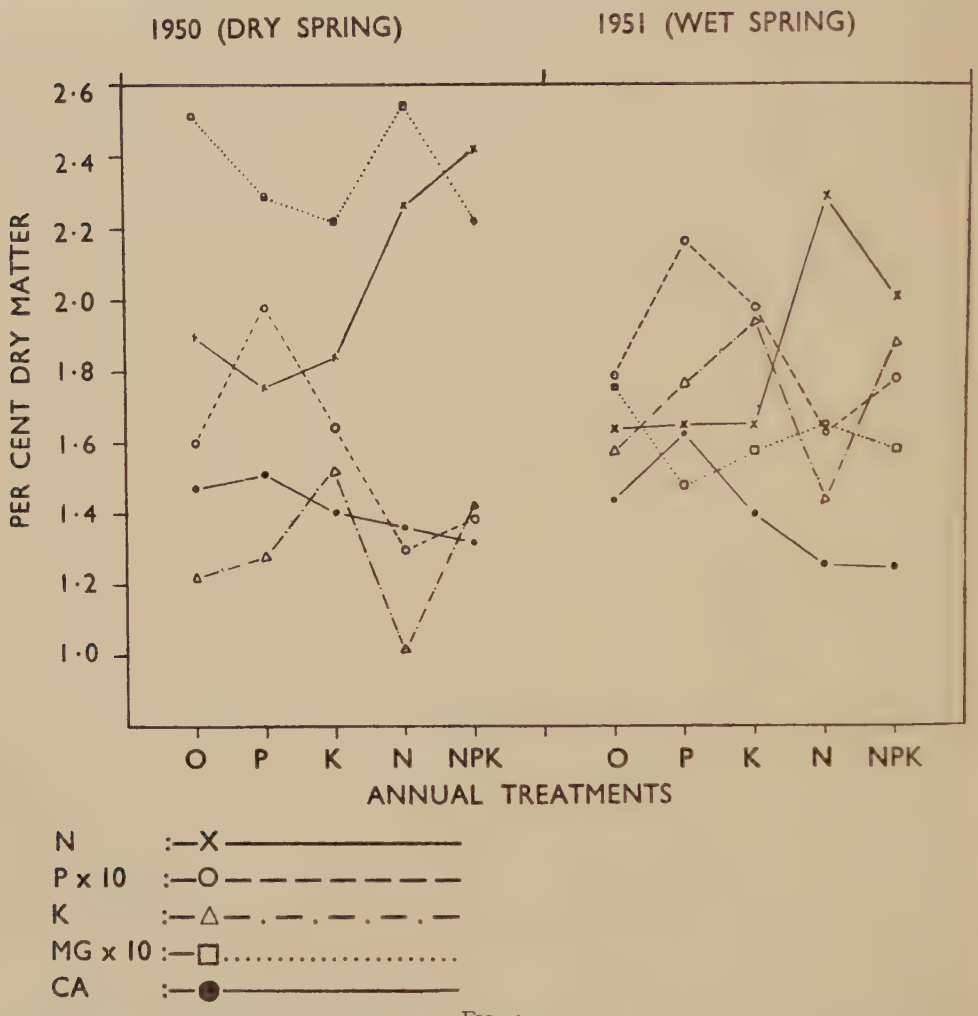


Fig. 3

Influence of nitrogen, phosphorus and potassium on the chemical composition of Cortland apple leaves 1950-1951

In both years, on the whole, there is a negative correlation between nitrogen and calcium, though only significant in 1951, and unlike N–K there is a reduction in leaf calcium, both with and without minerals, when applied nitrogen is increased. It has been noted that phosphorus and calcium are positively associated; an antagonism may exist between calcium and nitrogen.

The N–Mg coefficients are generally positive, though few are significant. Nevertheless, magnesium levels in the leaves do not correspond to increased levels of applied nitrogen or leaf nitrogen. Both Fig. 3 and Table III show that leaves from the untreated trees contain as much magnesium as those from the 16N plot, but that there is less on the potash and phosphate plots. Deficiency symptoms were more pronounced on the superphosphate block (Table I), all plots showing symptoms except the untreated and those receiving nitrogen only. Nitrogen probably offsets magnesium deficiency by the reduction of potassium and by its antagonism to phosphorus. The appearance of the symptoms with the complete fertilizer mixtures containing 16% nitrogen is believed due to the antagonism of the potassium ions which are supplied in the mixture, and not to phosphorus which remains low.

In view of the reasonably high level of potash in the soils of the Annapolis Valley, it is to be expected that in seasons of high rainfall the protective role of nitrogen will be reduced by leaching, with an accompanying magnesium deficiency. The tendency towards magnesium deficiency due to the use of more superphosphate and less nitrogen is offset by the general use of dolomitic limestone.

Chemical composition of leaves at two dates of sampling.

It was observed that considerable variation occurred in the dates on which magnesium deficiency symptoms appeared and, in order to examine these differences, several plots were sampled on 1st October, 1951.

Table V.

Nutrient levels (percentage of dry matter) of Cortland apple leaves at two dates of sampling in 1951.

Treatment	Date sampled	N	P	K	Mg	Ca
Control; (4 plots) ..	15th July	1·64	0·180	1·58	0·175	1·44
(4 plots) ..	1st Oct.	1·67	0·154	0·89	0·111	1·23
3–5–10; (4 plots) ..	15th July	1·77	0·213	2·00	0·153	1·41
(4 plots) ..	1st Oct.	1·62	0·136	1·29	0·056	1·05

The trees in the plot receiving fertilizer at the rate 3–5–10 in the superphosphate block were partially defoliated early in September and at the last analysis they contained only 0·012% magnesium. From this it would seem that a concentration below 0·175% is undesirable. There is also a marked reduction in the concentrations of phosphorus and potassium as well as of magnesium in the leaves. Contrary to the findings of Boynton *et al.* (3), calcium also showed a marked reduction except in the superphosphate block.

DISCUSSION.

The orchard under study has undoubtedly benefited in yield and growth by applications of lime and nitrogen. The appearance, however, of magnesium deficiency symptoms in trees in the unlimed blocks and what appears to be incipient

potash deficiency (in leaves from trees receiving dolomitic limestone) indicates that certain treatments are having an adverse effect on tree vigour.

Unlike the results obtained by Boynton and his co-workers (2, 3), there were large differences in phosphorus, potash and magnesium levels between the two years. As has been shown, increases in the applications both of phosphorus and potash result in reduced levels of magnesium. No reason can be given for the 30% increase of potash in the wetter year in leaves from trees that had not received fertilizer of any kind for six years. It seems improbable that the relatively slight decrease of 6·4% of nitrogen in the leaf is associated with this phenomenon.

In both years the trees in the blocks receiving dolomitic limestone contained lower levels of all constituents, except magnesium, than the untreated blocks, and yet trees receiving lime are the most vigorous and produce the largest crops. The Cornell workers (3) found a decrease of phosphorus and potash only in leaves from the high nitrogen, high yielding trees: this is confirmed by the results obtained in the high nitrogen plots in these investigations. Also, there was less calcium in the leaves of trees in the limed areas, agreeing with the findings of Boynton and Embleton (4). There was less phosphorus also in the limed trees, particularly on the plots receiving superphosphate only. This occurred under conditions usually considered to favour the increased availability of phosphorus in the soil.

In these studies, the phosphorus content of the leaves definitely reflected the applied phosphorus on the unlimed plots, with a soil pH of 5·0. On the other hand, Hill *et al.* (10) failed to get a response to applied phosphorus in apple trees growing in sod with a pH slightly above 6·0, which corresponds to the pH on the limed blocks. It is apparent, therefore, that the utilization of phosphorus by the apple tree is greatly influenced by soil acidity and cultural methods.

The reduction of leaf potash in the presence of applied magnesium and of leaf magnesium in the trees receiving potash alone corroborates the results obtained by Boynton and Burrell (5) and Hill and Johnston (11).

The negative relationship between nitrogen and phosphorus is well established (2, 7, 11), but those existing between N–K and N–Mg, while reported (7, 14), have not been as clearly defined.

It has been pointed out above that the levels of potash are only depressed when nitrogen alone is applied to the tree, but when potash is applied as well, there is a corresponding increase in leaf potash, even in the presence of high nitrogen. Analyses of foliage from Wagener apple trees at this Station, which received 800 and 1,600 lb. per acre of a 9–5–7 fertilizer, have shown a consistent increase in both nitrogen and potash in the leaves at the higher rate of application, with a sharp reduction in leaf phosphorus. Boynton and Compton (2) have suggested that the positive N–Mg and N–Ca relationships which they observed may be due either to the rapid absorption of magnesium and calcium in the presence of nitrate ions, or to the replacement of these two elements by hydrogen in the exchange complex as a result of ammonium sulphate fertilization. It has been shown here that magnesium increases when the concentration of potash is reduced by applied nitrogen, and when phosphorus is reduced by nitrogen ion antagonism. Contrary to the results of these workers the N–Ca correlation was found to be negative. This is not unexpected in view of the positive relationship between calcium and phosphorus.

Assuming that the strongly negative correlations N–P and K–Mg (Group 1) found in these studies are expressions of ion antagonism, it follows that the remaining

ion inter-relationships will be profoundly influenced by them. Consistent with this observation the data show that N–Mg are negatively correlated with phosphorus, potassium and calcium, and that these latter are positively related to one another (Group 2). Furthermore, within the limits of this experiment, the absorption of nitrate ions into the tree is proportional to the supply and, if phosphorus is kept at a low level, the absorption of potassium and magnesium will proceed unhampered depending on their relative concentrations within the tissue (Group 3). In order to clarify the foregoing points, these three main groups of correlations are shown as follows :

Group 1	K–Mg	(—)	N–P	(—)	Ion antagonism.
Group 2	K–P	(+)	Mg–P	(—)	
	K–Ca	(+)*	Mg–Ca	(—)*	
	P–Ca	(+)	N–Ca	(—)	
Group 3	N–K	(±)	N–Mg	(±)	Ions vary as applied.

Walrath and Smith (15) have recently stressed the need for higher magnesium levels in New England apple orchards and indicate a critical level of 0·20% in the leaves. Boynton and Embleton (4) found incipient deficiency with 0·25% magnesium in McIntosh leaves. The critical level in the present investigation was found to be 0·175%. This may be corrected by the application of dolomitic limestone, but the possibility exists that its use for the purpose may result in the appearance of corky core, particularly in Cortland apples, this variety being particularly sensitive to boron deficiency, which may be induced by a high calcium/boron ratio.

SUMMARY.

Applications of nitrogen, phosphorus, potassium and magnesium (in dolomitic limestone) were reflected in the chemical composition of Cortland apple leaves. Severe magnesium deficiencies developed in the unlimed blocks in the year with higher rainfall and were associated with a critical level of 0·175% leaf magnesium. Incipient potassium deficiency symptoms appeared in trees receiving lime and nitrogen only, the leaves of which contained 1·0% of potassium or less.

Seasonal conditions during 1950 and 1951 profoundly affected the mineral content of leaves in that there was an increase of approximately 20% of phosphorus and potassium and a decrease of 34·8% magnesium in the year with the higher rainfall.

Ion antagonism appeared to exist within the pairs of ions, N–P and K–Mg, and possibly also N–Ca, but neither N–K nor N–Mg showed any direct correlations. It is suggested, therefore, that magnesium deficiency in apple trees is due to relatively high levels of potassium or phosphorus and may be mitigated by nitrogen applications, which serve to dilute the concentration of potassium ions or hamper the intake of phosphorus ions.

Analyses of leaves sampled ten weeks apart revealed a marked decrease in the concentration of potassium, phosphorus and magnesium.

ACKNOWLEDGMENTS.

Appreciation and thanks are expressed to Mr. H. J. Lightfoot for technical assistance.

* Signs reversed when dolomitic limestone applied.

APPENDIX I.

Influence of various fertilizers upon the growth of Cortland apple trees 1945-1950. (Increase in tree circumference in inches.)

Plot	Treatment	A No Treatment	B Limestone	C Limestone and Superphosphate	D Superphosphate	Average
1	0–0–0	2·9	3·5	3·6	2·2	3·05
2	0–10–0	2·8	4·4	3·2	2·4	3·20
3	0–0–5	3·0	3·4	3·5	1·0	2·73
4	3–0–0	4·6	3·7	4·6	3·3	4·05
5	9–0–0	4·7	5·6	3·9	3·9	4·53
6	16–0–0	4·4	4·8	3·8	3·8	4·20
7	0–10–5	2·5	3·4	2·9	2·8	2·90
8	0–5–10	2·9	4·0	2·4	2·5	2·95
9	3–10–5	4·6	4·8	4·8	4·1	4·57
10	3–5–10	4·3	4·4	4·5	2·9	4·03
11	3–1⅔–1⅓	2·7	4·5	3·5	3·5	3·55
12	9–10–5	3·3	4·8	3·2	2·9	3·55
13	9–5–10	4·6	5·2	3·6	2·9	4·07
14	16–10–5	5·0	5·9	3·3	3·7	4·48
15	16–5–10	5·3	4·7	4·4	3·7	4·53
	Average	3·84	4·47	3·68	3·04	

APPENDIX II.

Influence of various fertilizers upon the yield (lb. per plot) of Cortland apple trees 1948-1951 inclusive.

Plot	Treatment	A No Treatment	B Limestone	C Limestone and Superphosphate	D Superphosphate	Average
1	0–0–0	1,064	1,515	1,718	1,628	1,481
2	0–10–0	878	1,737	1,914	1,410	1,485
3	0–0–5	847	1,830	2,152	1,147	1,494
4	3–0–0	2,017	1,970	1,976	1,998	1,990
5	9–0–0	2,425	2,510	1,650	1,920	2,126
6	16–0–0	1,897	2,107	2,862	1,984	2,213
7	0–10–5	619	1,645	2,399	2,165	1,707
8	0–5–10	880	1,596	2,575	1,668	1,680
9	3–10–5	753	2,551	2,753	2,568	2,156
10	3–5–10	1,154	1,929	2,691	1,731	1,876
11	3–1⅔–1⅓	1,563	1,778	2,213	2,343	1,974
12	9–10–5	1,970	2,252	2,044	2,109	2,094
13	9–5–10	2,355	2,914	2,397	1,878	2,386
14	16–10–5	1,925	2,637	2,573	2,860	2,499
15	16–5–10	1,774	2,205	1,843	1,967	1,947
	Average	1,475	2,078	2,251	1,958	

REFERENCES.

(1) *Beattie, J. M.*, and *Ellenwood, C. W.* (1950). A survey of the nutrient status of Ohio apple trees. Proc. Amer. Soc. hort. Sci., **55**, 47-50.

(2) *Boynton, D.*, and *Compton, O. C.* (1944). The influence of differential fertilization with ammonium sulfate on the chemical composition of McIntosh apple leaves. Proc. Amer. Soc. hort. Sci., **45**, 9-17.

(3) ——— *Burrell, A. B., Smock, R. M., Compton, O. C., Cain, J. C.*, and *Beattie, J. H.* (1950). Responses of McIntosh apple orchards to varying nitrogen fertilization and weather. Cornell Univ. agric. exp. Sta. Mem. 290.

(4) ——— and *Embleton, T. W.* (1950). Further studies on magnesium deficiency of the apple and its control. Proc. Amer. Soc. hort. Sci., **55**, 21-6.

(5) ——— and *Burrell, A. B.* (1944). Potassium induced magnesium deficiency in the McIntosh apple tree. Soil Sci., **58**, 441-54.

(6) *Brough, C. R.* (1950). Potash deficiency in apple trees. J. Dept. Agric., Victoria, **48**, 456-7.

(7) *Cullinan, F. P.*, and *Batjer, L. P.* (1943). Nitrogen, phosphorus and potassium interrelationships in young peach and apple trees. Soil Sci., **55**, 49-60.

(8) *Eaves, C. A.* (1951). Quality of apples as influenced by nutritional treatment. Nova Scotia Fruit Growers' Assoc. ann. Rept., **88**, 91-4.

(9) *Harlow, L. C.*, and *Whiteside, C. B.* (1943). Soil survey of the Annapolis Valley fruit growing area. Dominion of Canada Dept. of Agric. tech. Bull., 47.

(10) *Hill, H., Johnston, F. B., Heeney, H. B.*, and *Buckmaster, R. W.* (1950). The relation of foliage analysis to keeping quality of McIntosh and Spy varieties of apples. Sci. Agric., **30**, 518-34.

(11) ——— and *Johnston, F. B.* (1940). Magnesium deficiency of apple trees in sand culture and in commercial orchards. Sci. Agric., **20**, 516-25.

(12) *Kelsall, A.* (1951). Quality of apples as influenced by nutritional treatment. Nova Scotia Fruit Growers' Assoc. ann. Rept. **88**, 95-7.

(13) *Lindner, R. C.* (1944). Rapid analytical methods for some of the more common inorganic constituents of plant tissues. Plant Physiol., **19**, 76-89.

(14) *Nightingale, G. T.* (1942). Potassium and phosphate nutrition of pineapple in relation to nitrate and carbohydrate reserves. Bot. Gaz., **104**, 191-223.

(15) *Walrath, E. K.*, and *Smith, R. C.* Survey of forty orchards. (Eastern States Farmers' Exchange Communication.)

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REVIEWS

PERPETUAL FLOWERING CARNATIONS. By R. J. Morton. (London: W. H. & L. Collingridge, Ltd. 1953. Pp. 79, illus. Price 10s. 6d.)

This is a small book dealing with the cultivation of perpetual-flowering carnations under glass. It will be of value to amateurs who intend to grow these plants as a hobby and it has many useful points which would be of help to the commercial grower.

The early chapters give practical details about temperatures, ventilation, heating and shading. Mr. Morton does not mention that constant attention is needed for adequate maintenance of heated glass; some amateurs, on reading this book may not appreciate that the care of heated glasshouses is a full-time occupation. Clear instructions are given on propagation, the treatment of the rooted cuttings and the care of the mature plant, but the amateur grower would find the varying statements concerning the necessary temperatures rather confusing. Later chapters outline operations such as staking, watering and feeding and the final chapter is devoted to descriptions of insect and fungus damage and the usual methods of control. A good deal of common sense information, often lacking in accounts of cultivation, is included in this first portion of the book.

Mr. Morton then goes on to discuss commercial methods and soilless culture. The second half of the book, which deals with these two aspects of cultivation, is interesting but there is not sufficient detail to enable a reader to embark on either method without further information. A descriptive list of varieties is included as well as a chapter on raising carnations from seed. The book is well indexed and contains a number of clear photographs of varieties and operations. For those who already have a knowledge of greenhouse management it will furnish much useful information.

M.P.

STUDIES IN BRITISH BEECHWOODS. By J. M. B. Brown. (Forestry Commission Bulletin No. 20. London: H.M. Stationery Office. 1953. Pp. 100, illus. Price 12s. 6d.)

This bulletin is the fruit of a comprehensive survey of beechwoods in Britain carried out in 1948–50 and it is designed to assist all who are concerned with the silviculture of the beech. Part I deals briefly with history, systematy, phenology and distribution. In Part II our beechwoods are classified on the basis of soils, and growth in relation to site factors is discussed. Part III deals principally with the silviculture of beech—mixtures, under-planting, thinning, rotations and coppicing—and with its establishment in the four distinct sets of conditions in which it is normally raised, viz. under mature pure or mixed forest suitable for natural regeneration, on clear-felled woodland sites, on chalk downland, and on derelict woodland areas. Records of the stands examined and age-height graphs for different soil sites are given. The twenty-eight figures consist mainly of excellent photographs of beechwoods of various ages on various soils.

Beech can be accepted as native only in the southern counties of England and in south-east Wales, and its present wide distribution is chiefly traceable to extensive

plantings between 1720 and 1850. The greater part of Britain is climatically suitable for its growth and beech is tolerant of the soil in most districts. Its future as a forest tree is linked with the increased use of its timber, with its suitability for underplanting and with the desire to preserve an ornamental native tree. A revival of its popularity is expected.

J.D.

THE GEOGRAPHY OF THE FLOWERING PLANTS. New Edition. By R. Good. (London, New York and Toronto: Longmans, Green & Co. Ltd. 1953. Pp. iv+452, 75 line drawings, 9 maps in colour and 16 photogravure plates. Price 50s. net.)

This book in its original edition suffered a considerable handicap, for although the manuscript was completed in 1939, publication was held up by the war and it did not appear until 1947. It is therefore fourteen years now since the original manuscript was written and during these years many new publications and papers bearing on the geography of flowering plants have appeared. One therefore looks in the new edition for material from these more recent works and it is certainly there.

The general arrangement into two parts remains the same; Part I (approximately two-thirds of the whole) presents the facts of Angiosperm distribution and Part II attempts to find explanations of them. In Part I there are chapters on floristic regions and on different types of distribution of families, genera and species. Chapters are devoted to the history and distribution of the British Flora, the distribution of plants in Dorset, and the geological history and past distribution of the flowering plants. Part II is mainly devoted to the factors of distribution and is rounded off with a chapter on Professor Good's Theory of Tolerance and one presenting general conclusions. Finally there are two appendices, the statistics of the world's land surfaces, and a list, actually the third edition, of discontinuous genera. Much of the expansion of this new edition (amounting to about fifty pages) is due to the incorporation of information from recent work, and new paragraphs and sentences have been added throughout. One result of this is that the bibliography, which is one of the most valuable parts of the book, has more than doubled and now contains some 629 references as compared with the original number of 295. In many cases this more recent work has meant a change in emphasis or viewpoint and certain parts have been improved and considerably rewritten. Numerical and similar facts have been reviewed, and corrected in many places. Especially are such minor changes obvious in many of the maps showing the distribution of families, genera, etc. Seventeen of these have been more accurately and critically drawn, but it is a pity that all the errors have not been corrected; for example *Primula veris* is still shown as absent from Orkney (p. 222).

From the point of view of readers of this Journal it is to be regretted that there is not a fuller reference to the centres of origin of cultivated plants. Such plants are of such vital importance that a more extensive treatment of their geography would have greatly increased the value of the book. As a work of reference it has already proved of great value and this new edition is a considerable improvement in this respect. Not only is the bibliography more extensive, as has been pointed out, but an entirely new "Index to Subjects" has been added.

It is perhaps inevitable, but none the less regrettable, that there has been an increase in price, from 30s. to 50s., but when allowance is made for the greater size

and the general rise in retail prices since 1947, the increase, whilst great, is not disproportionate.

P.S.G.

PLANT DISEASES. By F. T. Brooks. (Geoffrey Cumberlege, Oxford University Press. 1953. 2nd Edition. Pp. xii+457, 65 illus. Price 38s.)

In the preparation of this edition, the text of the first, published in 1928 and for some years out of print, was completely re-written by the author who was Professor of Botany in the University of Cambridge until 1948. The manuscript had already been sent to the publishers when the author's death occurred in March, 1952, just before the proofs were ready. A pathetic and very modest note to this second edition by W. J. Dowson, S. D. Garrett and N. F. Robertson, all former students of his, informs the reader that the author had previously asked for their help in proof reading but the task had, to their sorrow, to be undertaken by them alone. They state that the text has not been altered and is just as Professor Brooks left it. With his usual perspicacity, the author selected the best possible team and we are thankful that all the circumstances have allowed the reappearance of the book.

In those earlier days, from 1915 to 1928, before the first edition had appeared, there was great need for an up-to-date text book on plant diseases occurring in the British Isles and elsewhere; Professor Brooks supplied that need and gave short diagnoses and lists of references to original papers. The second edition carries on the good work of the first and is in the same style. The diagnoses and descriptions of diseases are short but they are adequate and just enough references are usually given to enable the reader to find his way into any particular subject.

The author says in his preface that because our knowledge of plant diseases has advanced greatly in recent years, this is not only a second edition but virtually a new book. It is indeed, for new diseases are described and modernization has been effected in nomenclature and in the discussion of cause and control. Fourteen of the 22 chapters are concerned with parasitic fungi and one chapter is devoted to each of the following: Introduction, Non-parasitic diseases, Viruses, Bacteria, Actinomycetes, Plasmodiophorales and Myxomycetes, Green Algae and, lastly, Fungicides. The parasitic fungi, the author's chief interest, are the most adequately dealt with and the remaining chapters provide useful introductions to the other causes of disease and to fungicides; more could not be expected in a book of this size. The arrangement is as before and is based on the classification of the causes of disease and not on the grouping of host plants.

An increase in the text is accomplished by the use of thinner paper, 457 pages compared with 386, and slightly longer lines of type, resulting in a volume not quite so thick as that of the first edition. There is no list of illustrations and the more economical system of reference by asterisk in the general index is again adopted. Only two of the former illustrations have been withdrawn and replaced by others (Figs. 35, 62) and some are additional (Figs. 39a, 52a, 59a). The reproduction of most of the photographs is improved. The type is clear and proof-reading has evidently been most carefully done. The few errors noticed are of minor importance as, for example, where words have been accidentally divided (pp. 4, 127); a chance mis-spelling of *Botrytis byssoidea* (p. 153); a page number "151" in the Index, under "Poplar", should read "153" and, referring to *Puccinia opizii* (p. 265), "imported thence" presumably should be "imported there".

Professor Brooks' work is once again welcomed as the latest British text book ; the well-worn and battered copies of the first edition may now be retired.

W. M. W.

PLANT ANATOMY. By KATHERINE ESAU. (London : Chapman and Hall, Ltd., New York : John Wiley and Sons, Inc. 1953. Pp. 735, illus. Price 72s.)

This well-produced book, intended for advanced students and teachers, should be of great service. It collates modern work on the anatomy of seed-plants. The submicroscopic structure of the cell and its wall, the form of the cambial cells, the problems of leaf-development, venation, peridermal activity, laticiferous elements, and so on, concerning which there has been intense research during the last fifteen or twenty years, are here brought together in a consistent treatment. Twenty chapters deal with the standard subjects, beginning with protoplasm and its inclusions and passing through the various tissues to the stem, leaf, root, flower, fruit and seed as the syntheses. Each chapter has its elementary introduction, which is followed by an excursion into the field of research and concluded with an invaluable bibliography. There are copious good line-drawings in the text, many being original, and eighty-five plates of splendid photographs illustrate what is probably the best introduction to the construction of higher plants. For those who can afford the book, there can be no excuse for not being up to date in all these matters. Yet, it is a rich brew to be taken gradually.

Afford ! Ever more costly is knowledge ! The library, therefore, and particularly the lending library, must take the place of the private owner. A few will buy this book on this side of the Atlantic, but every botanical library should see that it is available for consultation. In view of its size, however, the excellence of the illustrations, and the labour of preparation, the price is reasonable.

Here is an authoritative introduction to modern work by one who, as Professor of Botany in the University of California, has greatly helped to build it up. Nearly every account of this modern work is well done and thus the book is a stride forward. A glossary would give precisely the meanings, derivations and authorship of the descriptive terms, which are dispersed inconveniently and rather inconsequentially. The numbering of the text-figures, too, is likely to irritate some people. A sort of amphipetal decimal system is used : thus, 15·1 is the first figure in chapter fifteen, but 15·22 comes after 15·9, being the twenty-second. The treatment of corresponding chapters is also discrepant, histology in one place becoming tissue-systems in another, while morphology is generally degraded to mean external appearance. A list of contents at the beginning of each chapter would have remedied this and have expedited reference.

We have called the book an introduction because it seems to us a very necessary introduction to the absolute treatment of plant anatomy, which must be systematic on phylogenetic lines. The book fills the gap between the properly elementary and the great work of Metcalfe and Chalk. Thus, in this intermediate stage of imperfect knowledge, it may be useful to compare *Tilia* with *Nicotiana*, but in reality one is a Tiliaceous problem and the other a Solanaceous, and comparison may be superficial. That parallel evolution has been rife among seed-plants is not clearly explained, and is generally overlooked by research workers. So, false generalizations creep in. *Ficus elastica*, for instance, on p. 162, has a specialized kind of fig-leaf, paralleled by similar elaborations in other subgenera of *Ficus* as well as in other genera of the

Moraceae. There comes a stage when the usefulness of this intermediate approach, mixing up the lines of evolution, ceases and must give way to whole-hearted taxonomic treatment. Perhaps that is why the author omitted saprophytes, parasites, insectivorous plants, mycorrhiza and other obviously polyphyletic peculiarities. But it is easier to appreciate the bewildering diversity of plants, if it is realized that many adult features are convergent in superficial resemblance from phyletic lines with different modes of construction. Thus, the " simple leaf " and the " simple hair " are probably the most diverse. The analytic power of systematic botany should not be overlooked. Let us hope that a chapter on these lines may be included in a later edition, for it is beyond the powers of most botanists to simplify " Metcalfe and Chalk ".

E.J.H.C.

PHYSIOLOGY OF SEEDS. By W. Crocker and L. V. Barton. (Waltham, Mass: Chronica Botanica Company. 1953. Pp. xv+267, illus. Price $6.50.)

The scope of this book is indicated by its extended title " An introduction to the experimental study of seed and germination problems ". The authors explain, however, that their aim has been " to give a broad coverage of our present knowledge on seed and germination in a volume of moderate size " and that this is " an outline rather than a treatise ". To economize space, historical treatment of the subject has been avoided, certain topics, such as seed dispersal, have been omitted and references reduced to the minimum necessary to provide a background for the discussion—even so, they amount to some 1,100. Single chapters are devoted to the anatomy of seeds, seed production (including asexual seed formation), water relations, respiration, storage and life span, vernalization, embryo culture, and seed transmission of disease. Chemical composition, factors affecting germination, and dormancy are each allotted two chapters and three are devoted to metabolic and energy changes in seed development and germination. Not all these topics are discussed with the same thoroughness; the chapter on anatomy is very short, though reference is made to publications where fuller treatment may be found. In the chapter on seed production, mention is made of self-incompatibility in connection with alfalfa but no mention is made of the work of Crane and his collaborators at the John Innes Horticultural Institution. In general, however, a wide field is adequately covered and the book, which is beautifully produced, should prove a useful work of reference to workers in this field. Each chapter is followed by its own list of references and there is a final comprehensive author-index covering the names cited in the references.

M.C.V.

GARDENING IN WARM CLIMATES. By D. A. Herbert. (Sydney and London: Angus and Robertson. 1952. Pp. 245, illus. Price 30s.)

Those parts of the world that are characterized by almost frost-free, dry winters and by hot, wet summers provide a meeting place for many of the cultivated plants of both tropical and temperate regions. The coastal districts of Queensland and northern New South Wales form one of these areas, and there are others on the eastern shores of Africa, America and Asia.

The author of this book is Professor of Botany in the University of Queensland, but lest this knowledge should discourage the ordinary gardener, let it be said at once that Professor Herbert is clearly also a practical gardener and has approached his subject from this and no other point of view. The result is a manual, partly composed of useful suggestions and partly encyclopaedic, without being a mere catalogue of species, and it should, therefore, be of much assistance to the amateur but of comparatively little value to the specialist or to the advanced student of sub-tropical horticulture.

The book opens with three general chapters on preparation, planting and maintenance, and on weeds, pests and diseases in which the use of proved modern methods and materials are not neglected. Six chapters follow devoted to short descriptions, with notes on special characters, propagation, etc., of annual and herbaceous plants, bulbs and allied plants, shrubs and hedge plants, climbers, trees, and fruits. The arrangement here is by scientific names in alphabetical order, but common names are also listed with the appropriate cross-references. The remaining seven chapters on the vegetable garden, the bush-house, orchids, water plants, succulents, lawns, and plants suggested for a new garden also contain plant descriptions and, in addition provide information on the particular cultural needs of each group of plants. The term " bush-house " may need a word of explanation. It is applied to a shaded house or shed, which in some respects takes the place of the greenhouse of temperate countries. In it are grown, in the soil or in pots or baskets, the various shade-loving ferns, club mosses and foliage plants that are a common feature of household decoration in warm countries.

There will doubtless be some gardening enthusiasts who disagree, here or there, with the author's opinions or with his treatment of a subject. For example, the Bougainvillea enthusiast may consider that one-third of a page can scarcely do justice to so colourful a group of plants, and that in any case the white variety should at least receive a mention (despite its incredibly dreary appearance when the flower bracts wither). Again, the purist may prefer to find Arum lilies under *Zantedeschia* rather than under the older and more melodious name of *Richardia*. But all will surely unite in expressing gratitude to Professor Herbert for cutting every vestige of the poetic cackle that is apt to mar many otherwise useful books on gardening. His approach throughout is direct, simple and practical. Who, for instance, in describing the Avocado could improve for brevity and clarity on : " The taste for Avocado is usually an acquired one, but is worth acquiring " ? The shortness of the glossary of horticultural and botanical terms indicates the simplicity of the style used.

It remains to mention that the book contains an adequate subject-index and a number of good photographs, some showing most striking and unusual plants. In the unlikely event of the reviewer being transferred to a sub-tropical region he would, being an amateur gardener, be glad to take this book with him.

G.K.A.

OBSTBAU GRUNDLAGEN, ANBAU UND BETRIEB. (Fruit Growing.) 3rd revised Edition. By F. Hilkenbäumer. (Berlin and Hamburg: P. Parey. 1953. Pp. 355, illus. DM 28—bound.)

The 3rd edition of Hilkenbäumer's book is reset in slightly smaller type. This

has given the author a chance, of which he has availed himself, of regrouping and rewriting. As a result the style is now more concise in many places and the information is presented more neatly.

Concurrently the number of photographs has been greatly reduced and, instead, clear and useful schematic drawings have been incorporated to illustrate the author's point more clearly, especially with regard to pruning. In the chapters on physiology and management, and in others, a more fundamental approach has been sought. In general the book has been brought up to date, thus a chapter has been included on the use of growth substances, the treatment of plant protection has been modernized both as regards chemicals and equipment. Some details are given on frost protection by irrigation but only a brief note is given on the use of fans for the same purpose as, in their present form, they are still considered uneconomical. One suggestion is new to the reviewer, namely that for preventing cold air stagnating near the ground by driving a flock of sheep through the orchard during the night. The bibliography has been considerably enlarged. Authors' names are given at the end of each chapter and the full reference appears in the comprehensive bibliography at the end of the book. To those who read German this new edition can be strongly recommended.

D.A.

STRAWBERRY CULTIVATION. By Edward Hyams. (London: Faber & Faber Ltd. 1953. Pp. 162, illus. Price 18s.)

In this book Mr. Hyams describes the history and origin of strawberry varieties, including the remontant or ever-bearing varieties of which he is so fond. He sets out to show how, by the use of summer-bearing strawberries, the autumn-fruiting French and German ones and by the employment of cloches, both alone and coupled with electric soil warming and additional lighting, strawberries can be picked during most months of the year.

Mr. Hyams has rather strong views on strawberry varieties and on the production of new sorts. He takes the attitude that in this country we have spent too much time and money "in propping up Royal Sovereign" when such time and resources would have been much better spent in the breeding of new varieties with resistance to virus such as he says is done annually in France. This suggestion rather oversimplifies the work of the plant breeder. It is, of course, a simple matter to raise strawberry seedlings and to put them on the market, with strong claims for their virtues, such claims so often having subsequently been found to be unjustified. One can perhaps support Mr. Hyams' suggestion that we should be a little more bold in trying out autumn-fruiting strawberries in this country and there are, at the moment, commercial growers becoming interested in the subject. That financial gain awaits them is, however, rather a matter of speculation.

Mr. Hyams is presumably drawing on his own experience of varieties, but his suggestion that Tardive de Leopold is of "excellent flavour" would hardly find general acceptance. In his list of varieties for early season on page 62, he mentions Cambridge 420. This presumably is a misprint for Cambridge 422, while in repeating the same list on page 71, the number is given as Cambridge 410.

When dealing with the production of strawberries out-of-season, that is from November to April, the author recommends the use of ever-bearing varieties for

giving fruit from November to January, and discusses the use of soil warming and additional lighting for this purpose. Out-of-season production in this way has already been achieved, but it can prove to be a very expensive procedure. It is true, as Mr. Hyams states, that the ever-bearing varieties will continue flowering and cropping until well into January or even early February, simply by giving them sufficient warmth and extending their length of day to about 16 hours by means of ordinary electric light bulbs; but the crop produced in the depth of winter and the rate of ripening of the fruits is much slowed down under this method unless light is supplied from mercury vapour lamps to influence photosynthesis. Incidentally, it has been found elsewhere in this country that the electric light bulbs need not be placed at intervals of 2 ft., as used by Mr. Hyams, since the plants respond to even a weak light given by 25 watt lamps at greater intervals.

When writing of the forcing of strawberries to crop in March and April, of which he admits he has had no personal experience, the author appears to be a little confused. Where Royal Sovereign is used for forcing, the plants being brought into the houses during December, there is no need to go to the extent (page 115) of giving the plants short day length during September and October, since the plants to be forced will have already passed through their normal flower initiation and dormancy period in the open. It is only when the summer-fruiting varieties are to be forced before the normal dormancy period is completed, that steps have to be taken to ensure flower initiation by short day length at an earlier date or artificial chilling of the plants followed by additional high intensity illumination.

The chapter dealing with Diseases and Pests and their control contains a number of errors. For example, in referring to one of the species of eelworm attacking strawberries given as *Tylenchus devastatrix*, it is stated that it causes " plants to wilt and decay ". The symptoms caused by this eelworm, now named *Ditylenchus dipsaci*, are not in fact wilting and decay but characteristic thickening and distortion of the petioles and leaves. The advice to remove affected plants and plant new ones in their stead " to be on safe ground " is not very sound in the case of this eelworm which can infect a number of common weeds.

F.A.R.

PUBLICATIONS RECEIVED.

A SURVEY OF AGRICULTURAL, FORESTRY AND FISHERY PRODUCTS IN THE UNITED KINGDOM AND THEIR UTILISATION. The Development Commission. (London : H.M. Stationery Office. 1953. Price 7s. 6d.)

This book contains a report on the findings of a survey team, which was appointed in 1948 by the Development Commission to undertake an enquiry into agricultural, forestry and fishery products and wastes and their uses in the United Kingdom.

The report contains a great deal of information on the production and sources of supply of the main home and imported agricultural, forestry and fishery products, on their main uses, and on the by-products derived from them.

It is hoped that on the basis of the essential facts which are presented in the

report, the promotion of research into the better and fuller utilization of the by-products may be stimulated and encouraged.

PRESS GUIDE TO BRITISH CHEMICALS AND THEIR MANUFACTURERS. Issued by the Association of British Chemical Manufacturers. (Cambridge : W. Heffer & Sons, Ltd. 1953. Pp. 76. Free on application to Association of British Chemical Manufacturers, 166 Piccadilly, W.1.)

NOTICE TO CONTRIBUTORS

1. The **Journal of Horticultural Science** is an official organ of the Horticultural and Agricultural Research Station, Long Ashton, Bristol, and the Horticultural Research Station, East Malling, Kent.

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2. All **manuscripts** should be in double-spaced typewriting, with a good margin, and should be addressed to the Editors, East Malling Research Station, near Maidstone, Kent, England. Papers must be written concisely. Historical reviews should be as short as possible and only such references to literature as bear directly on the subject should be included. Tables and illustrations, if any, must be only such as are absolutely essential for clear presentation.

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7. The **scientific names** given in the "List of Common British Plant Diseases", published by the British Mycological Society (Cambridge University Press, 1944) and "Common Names of British Insect and other Pests", published by the Association of Applied Biologists (The Mendip Press Ltd., Bath, 1947) must be employed.

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